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Propagation of Clonal Hevea brasiliensis *by Cuttings*

D. W. Levandowsky
United States Operations Mission to Vietnam

Cuttings taken from young seedlings of most woody species root easily. However, when the cuttings are taken from mature specimens of some of these species they root with difficulty or in some cases not at all.

Hevea brasiliensis is such a species. Many attempts were made to reproduce clonal material of *Hevea* by cuttings but there is no record of them ever producing roots (Baptist, 1939; Stahel, 1947; Wiersum, 1955) until the first successful rooting of clones Waringiana 4, Tjirandji 1, and Bodjong Datar 5 took place in September 1952 on Firestone Plantation in Liberia. The closest previous approach to rooting of clonal *Hevea* was by marcotage, a method by which the roots are formed on a shoot before it is cut off from the mother tree. This was accomplished several times since the selection of high yielding *Hevea* trees began (Swart and Rutgers, 1921; Gregory, 1951; Muzik, 1953).

DEVELOPMENT OF THE METHOD WITH *Cinchona*

The basic principle of the method by which *Hevea* is now being successfully propagated (by cuttings) was originally developed in 1944 with *Cinchona* spp. (Quinine) at Finca ' El Porvenir ' in Guatemala*.

Unlike *Hevea*, mature *Cinchona* cuttings can be rooted but the ' takes ' of cuttings in the past did not usually exceed five per cent. The roots obtained were weak and there was considerable mortality after rooting. The history of attempts to propagate *Cinchona* from cuttings is even older than those with *Hevea* (Groothoff, 1912) and these attempts were invariably given up as a bad job.

In El Porvenir high yielding mother trees of *Cinchona* were selected on the basis of assays of samples of bark. More than 9 000 trees were compared and the ' high test ' trees (in quinine or in total alkaloids) were at first propagated by the time-proven side-graft method. However, *Cinchona* trees growing in dense forest developed only a small crown at the tip of their elongated trunks. This furnished only a limited number of graftable scions per mother tree.

To produce more scion material per tree it was decided to attempt to increase the number of branches on individual trees by putting them in a horizontal position. The roots were dug carefully on one side of a tree, then the tree was lowered in the opposite direction and laid in a horizontal position. The freed roots were again covered with soil which was maintained high by cribbing.

Shoots soon appeared along the whole length of the top side of these horizontal stems. In appearance these shoots resembled seedlings in their

* Finca ' El Porvenir ' was leased by the U.S. Government in 1942 and held until 1948. *Cinchona* originally planted there in 1880 became a naturalized forest tree and was growing over an area of about 10 000 acres. The bark was harvested at first for war purposes and later for the strategic stockpile.

secondary juvenile stage which, in *Cinchona*, usually constitutes the period between six months and one year after germination.

Some of these sprouts were cut off and tested for rooting. The preliminary results were between 20 and 30 per cent ' takes '. The rooting procedure was gradually improved and the rooting percentages in some clones went up to 70 and 80 per cent. Individual batches gave ' takes ' of over 90 per cent.

The rooting medium is a special type of clay which has irreversibly lost its plasticity upon drying and oxidation*.

Approximately 50 000 softwood cuttings were rooted from clonal material in ' El Porvenir '. There could have been several hundred thousands of them. The propagation programme, however, was held within the limits of ' maintenance of clonal material '.

This method of propagation has now replaced grafting methods in the plantations maintained by Merck and Co. in Guatemala and Costa Rica.

RECESSION (REJUVENATION) TO ELEMENTARY PHASES IN PLANTS

GOEBEL (1892; quoted in KRENKE, 1950 and in ALLSOPP, 1954) in the late 1890s was the first to make a serious study of the phenomenon of rejuvenation. In advancing his theory of heteroblastic development in plants he showed that induced nutritional deficiencies can retard the passage from the juvenile to the adult phase and in some cases actually reverse the process. This early work is being revived and, with some exceptions, confirmed by a number of workers.

ALLSOPP (1954) indicates that a number of reversals to juvenile phase recorded recently could be explained on the basis of nutritional deficiencies. In his own work Allsopp arrived at controlling, at will, the development of adult or juvenile leaf forms on ferns by regulating the supply of carbon and of mineral nutrients.

HUDSON and WILLIAMS (1955) observed reversals to the juvenile form in adventitious sprouts of raspberries, ' when they grow from (*a*) thin roots or (*b*) small pieces of roots or (*c*) pieces of dying roots or (*d*) at a high temperature '. Also subsequent reversals to the juvenile form were observed by these authors when the plant developed basal galls caused by *Bacterium tumefaciens*. In this case, however, the cause could have been either traumatic or indirectly nutritional, or both.

A good example of loss of one specific characteristic of maturity in *Hevea* because of injury can be observed by driving along Route 2 in Firestone Plantation in Liberia during leaf-shedding time. Various clones of *Hevea* growing along Route 2 shed their leaves at different times in the dry season†.

In areas of clones which have lost their leaves, green-leaved clusters of sprouts are noted on trees along the roadside growing on branches of trees which were cut back in order to reduce the shading of the road. The injury to these trees caused them to produce a new type of growth which has lost the mature trait of leaf shedding. The wide internodal spacing and the large size of the leaves resemble younger forms of *Hevea*. It is possible that

* Found in the wet tropics at elevations from 3 500 to 5 000 ft in certain profiles in low B horizon, on various parent materials which are not too high in silica content. A clay soil having similar property was found recently at Blao Experiment Station in Vietnam.

† This is a phenomenon indicating the high degree of individuality of biochemistry in different clones. It also indicates a full maturity in trees. In young seedlings (up to two years old), there is no shedding of leaves in the dry season.

many of these sprouts would produce roots if used as cuttings. Sprouts of this type which appeared on trees uprooted by wind were rooted. Cuttings taken from normal branches of *Hevea* which exhibit the leaf-shedding characteristic have never produced a single root in a number of trials by the author and other workers.

Personal observations and discussions with botanists and horticulturists who are familiar with both temperate and tropical vegetation indicate that such recessions to elementary forms are more widely encountered in the tropics than in temperate climates. The degree of reaction to injury or other adversity is also perhaps greater in the tropics. KRENKE (1950) observed that the ratio of flowers to fruits in cut-back plum trees in the humid subtropics is wider than on cut-back plum trees growing in a cold and dry climate. It is known to orchardists that the wide flower-to-fruit ratio is a juvenile character in fruit trees and that there is a recession to wide ratios again after the fruit trees are cut back.

Since the serious study by STOUTEMEYER (1937) of rooting of cuttings made from adventitious shoots produced on pieces of roots of apple tree there seems to have been a great deal of attention paid to the adventitiousness of shoots as the necessary ingredient for the renewal of the ability to produce roots. Considerable effort is directed into producing adventitious shoots on sphaeroblasts of fruit trees in order to produce rootable cuttings (WELLENSICK 1952; HATCHER and GARNER, 1954).

In the writer's experience with rooting of *Cinchona* and *Hevea* clonal cuttings, there was not one case of proved adventitious origin among them although a number of cross sections of wood were made. In fact, almost all of the cuttings were taken from material where the dormant buds from which the shoots grow were plainly visible. At any rate a statement can be made that a ' rejuvenated ' shoot which produces rootable cuttings does not have to be adventitious to do so.

The term ' rejuvenation ' or ' juvenile ' applied to plant material developed on mature individuals is, in the writer's opinion, quite unsatisfactory. Very often the loss of mature characteristics (in our case the reluctance to form roots in hard-to-root species) is not associated with distinct changes in gross morphology. Besides, the loss of adult characteristics is also sometimes shown by senile specimens as a matter of decline in vigour. In fact certain types of senile *Cinchona* material produced roots more readily than the cuttings taken from vigorous adult trees.

Instead of using the expression ' reversal to juvenile phase ' this writer proposes to use ' recession into elementary phase ' and instead of ' rejuvenated shoots ' ' elementary phase shoots '.

Perhaps somebody will propose a better term? It is about time, however, to leave the concept of juvenility where it belongs, with juvenile plants.

By the same token the expression ' physiological age ' when used in connection with recession into an elementary form is probably incorrect most of the time.

DEVELOPMENT OF THE METHOD WITH *Hevea*

The early work (from August 1951 to April 1952) was conducted in the U.S.D.A. Plant Introduction Garden, Coconut Grove, Florida*.

* A cooperative project sponsored by the Firestone Plantation Company.

The only adult material available for full-scale tests (including cutting back, uprooting, or forcing into a horizontal position) was a group of seedlings about five years old and presumably past the juvenile condition.

However, by the time the primary essentials of a method were developed, the weather became too cold (the temperature drops close to freezing during the night even in Southern Florida). In consequence none of the cuttings taken from five-year old trees ever rooted.

Nevertheless, an important part of the presently used method, the precallusing of cuttings at an angle, was developed in Florida. Some experience was also gained with the continuous-mist spray. Also a new rooting medium, carbonized clay, was developed.

From May 1952 to March 1958 work was continued at the Firestone Plantations in Liberia. Some stumps from old budwood nurseries of Bodjong Datar 5 and Waringiana 4 were brought into the Botanical Research propagation area and after a severe cut-back planted there in a horizontal position. Also some ' runt ' trees of Tjirandji 1 were brought in and also put in a horizontal position. Cuttings taken from these mother plants were the first clonal *Hevea* cuttings to be rooted.

For several months after this the results obtained were uncertain. Only occasionally, a few cuttings rooted. However, in January 1953 one batch of 100 cuttings was taken from old budwood stumps of Waringiana 4 which had been cut back and allowed to branch out in a manner shown in *Figures 1* and *2*. Thirty one cuttings rooted from this batch. From that time on the rooting of cuttings from certain clones (such as War. 4, Tjir. 1 and Har. 2) became a matter of routine. Other clones (BD 5 and Har. 1, for example) were resistant to rooting, seldom going over 10 per cent.

The rooting medium was improved (at present a medium from crushed bricks is used). The spraying time was changed from 24 hours to daylight hours only. A root-promoting substance (β-2, 4-dichlorophenoxypropionic acid at 0·5 mg per gramme concentration in talcum powder) was selected among 14 substances tried at various concentrations (70 combinations in all). The rooting gradually attained a level of 40 to 50 per cent on an average, with some batches producing as much as 70 per cent ' takes '.

Foliar feeding with urea did not increase the percentage of ' takes ' but produced earlier rooting.

In one test, after 45 days, the control gave 28 per cent and urea gave 47 per cent rooting. After 75 days both treatments gave 75 per cent rooting.

The survival after transplanting of rooted cuttings into hardening beds and also from hardening beds into the field presented a problem. At first a great deal of protection was given to the cuttings such as shading and spraying. Now a much simpler method is used: no shading at all and only light spraying for one week when the sunshine is intense. After this only light watering is needed once a day, in dry weather. The cuttings can be transplanted into the field after two weeks in tubes. In cases where the field planting is to be delayed, the rooted plants can be kept in tubes for two or three months by keeping the plants fairly dry.

The survival of a batch of 500 rooted cuttings in the field after one year (transplanted in September 1956) was 74·4 per cent for the fertilized rows and 64·2 per cent for the control rows.

Figure 1

Figures 2 and 3

The method as it is practised now is detailed with illustrations in the remainder of the text.

MOTHER PLANTS AND PRECALLUSING OF CUTTINGS

In *Figure 1* are mother plants, the old budwood stumps which were cut back several times*. At the stage shown, when the leaves are fully developed but are still quite succulent and still drooping, the cuttings are ready for the precallusing by bark-scission†.

Figure 2 shows the cutting off of the superfluous leaves with a bud-grafting knife. *Figure 3* shows the method of bark-scission.

Figure 4

The depth of scission is more or less self-regulating. A light pressure easily puts the knife through the outer tissues until arrested by the fibres of the xylem. The slicing must make a complete circuit around the stem at the angle shown and with a pointed lower extremity.

PREPARATION OF A CUTTING FOR THE ROOTING BED

After about two weeks from bark-scission a callus has formed at the sliced cut as seen in *Figure 4*. A swelling of the pointed tip is visible. At this time the cuttings are harvested as shown in *Figure 4* and are immediately put in very wet burlap bags which are kept in the shade.

When brought to the propagation shed the cuttings are kept moist while they are being worked on and are covered with moist cloth when not in bags or buckets‡.

* A method of cutting back fruit trees a number of times in order to produce rootable cuttings was independently developed at the East Malling Experiment Station (GARNER and HATCHER, 1955). The fruit trees in nursery rows were cut back low to the ground several times until they formed a veritable hedge. Cuttings taken from these hedges root very well while only very low ' takes ' are obtained from normally developed trees.

† Bark-scission—the act of making a single cut through the bark so as to make a complete separation of that above and below the cut around the entire circumference of the stem. This differs from ringing only in that no bark is removed.

‡ At Firestone Plantations there is an excess of old buckets which are used as containers. At no time are the cuttings submerged or standing in water.

The excess tip below the callus is next trimmed off. If the cuttings are harvested at the right time (not sooner than 10 days nor later than 20 days after bark-scission) no latex appears when trimming is done. Of course the wounding of callus is avoided when trimming. This is very important because, if the latex oozes out of the cut tip of the cutting, rotting will take place in the rooting bed, starting at the wound.

The tip is painted with Fermate paste. Another method is to dip the whole cutting in a water suspension of Fermate. Before dipping, the leaves are trimmed to about half their size. This is accomplished by bunching all leaves in one hand and cutting them off in one or two cuts with sheep shears.

If the root-growth substance is used, it is usually made into a thin paste by adding water to the talcum mixture (just before use) and by painting the tips with a brush or by dipping the tips into the paste.

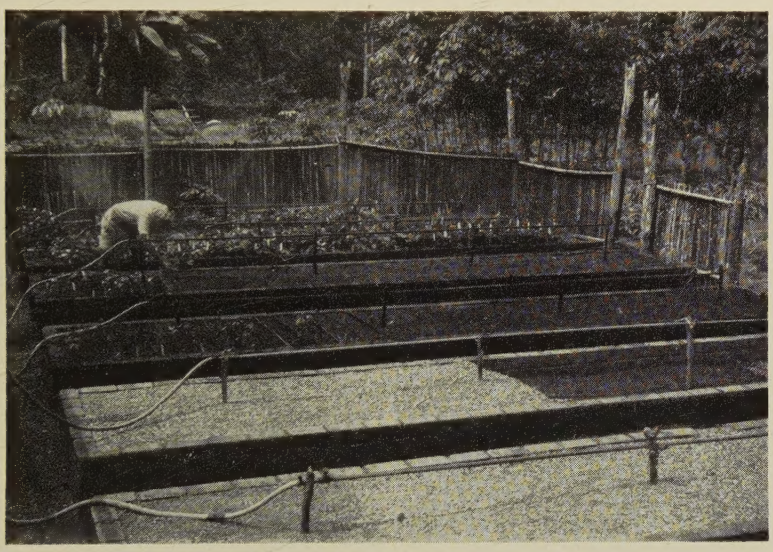

Figure 5

Rooting beds

Figure 5 shows the propagation beds. Drainage is provided by sloping the earth floor of the beds towards each end and by a layer of crushed rock placed at the bottom of the beds. The crushed rock is covered by a plastic screen of 14 × 18 mesh (per inch). This screen seems to last indefinitely. The rooting medium is crushed brick which is screened through a screen of $\frac{1}{2}$ inch mesh.

The pipes with spray nozzles, spaced 6 ft apart, rest on forked sticks about 18 in. above the level of the finished bed.

The planting of cuttings in beds is accomplished with a pointed stick about 12 in. long and $\frac{3}{4}$ in. in diameter. A hole is punched and a cutting is inserted into the hole to a depth of about 2 in. Punching the next hole with the stick presses the rooting medium around the cutting previously planted.

The fence around the beds is to keep the wind from blowing the spray away from the cuttings.

In a large scale propagation unit there is no need for brick walls. If drainage is provided by sloping and drainage ditches, then large areas can be covered with a layer of crushed brick or some other easily drained porous material. Not much fencing is needed on large areas. If spray nozzles are placed high not as many will be needed.

ROOTING OF CUTTINGS

Figure 6 shows the purpose of the pointed tip at the cut end of the cutting. The first root comes out there. For that matter most of the roots emerge at or near the tip where swelling has developed (*Figure 4*). The writer for lack

Figures 6 and 7

of a better term calls this ' concentration of effort '. To this and to precallusing, which prevents wounding in the phloem and bark area, the writer attributes the success in rooting. Of course the shoots too must be of the right type.

The following is the water régime while cuttings are in the rooting bed. While the cuttings are being planted it is important to keep their leaves moist by turning the mist on every 10 or 15 minutes. Also the planting should be done either early in the morning or on cloudy or rainy days.

For the first 2 to 4 days (depending on season) the newly planted cuttings must receive spray for 24 hours. After this, the spray is operated during the daylight hours only.

If the batch is uniformly rooted and is kept in the bed for more root growth or some other reason then the mist is kept on only during intense sunlight (10 a.m. to 4 p.m.) on sunny days.

TRANSPLANTING IN TUBES

Figure 7 shows the ' potting ' operation. In this case, the tubes are not of tar paper but of insulating felt with small holes in it. This material does not crack and can last for many transplantings.

The tubes are prepared as follows: the rings of rattan rope are made of the same diameter by tying them on a bamboo stick about 2½ in. in diameter. The rings are slipped over the rolled sheet of felt and the tube is half-filled with the potting mixture. After light tapping of the upright tube against the floor the earth mixture (which is slightly moist) settles down and when the tube is lifted stays in it although there is no bottom.

The mixture is about one third laterite gravel and two thirds fairly good garden soil.

HARDENING AND TRANSPLANTING IN THE FIELD

The tubes of transplanted cuttings are lined against a bamboo rail in two or three rows. For about one week they will get some spray during the hot period of the day. After that they are only watered with a hose during dry weather, once a day.

Transplanting from the tubes into the field takes place after about one month.

At first the rattan ropes are cut and the paper is opened to make sure that roots are not hooked in the holes of the tubes. Then the tube is lowered into a hole and the paper of the tube is pulled out by alternate pulling with one hand at a time with a slight swinging or rotary action. The earth is pressed against the transplant with a stick.

No watering at all was done when transplanting into the field was effected. This would make the field planting expense too high in many locations.

GROWTH PROGRESS IN THE FIELD

Figure 8 shows Waringiana 4 cuttings eight months after transplanting to the field. Those familiar with the growth of young rubber will appreciate the rapid progress of these young trees.

This batch of cuttings compared very favourably with the best budded trees transplanted in the field at the same time. Yet the cuttings were from seven to nine months younger than the buddings if the age is measured from the time of germination of seeds for the rootstocks of buddings and from the time of rooting of the cuttings.

Survival in the field also compares favourably with the survival of buddings transplanted at the same time. In fact the cuttings were planted at the end of September, after all the field planting of buddings was completed. In Liberia the dry season starts in November. So the cuttings got only the tapering-off rainfall of the dry season.

Survival data were 74·4 per cent for the fertilized rows of trees and 64·2 per cent for non-fertilized trees. This was on the basis of 500 trees, half of them fertilized once, six months after planting.

Figure 8

Figure 9

YOUNG TREES FROM CUTTINGS

Figure 9 shows the root development on a Waringiana 4 cutting two years after transplanting into the field. Usually one or sometimes two or three pivotal roots become predominant and acquire some of the characteristics of the normal tap roots produced by seedlings.

From all appearances the tapping of clonal rubber from cuttings could be started at least at the same time as with buddings if not sooner.

TOP-BUDDING OF CUTTINGS

Top-budding of Waringiana 4 cuttings with FX–614* has also been carried out in a nursery.

Although the trees were transplanted in October, which is rather late, all of them are doing quite well at the time of writing.

The method of transplanting was as follows: after budding, the first flush was allowed to develop before the budded trees were dug out and root-pruned. To allow the trees to get over the shock of loss of roots they were kept under spray in the rooting beds for one week. Then the spray was cut off and the trees remained in the bed for another week. By this time the wounds were pretty well healed and a few new adventitious roots began to appear. At this time the trees were taken out of the beds, the roots were dipped in a clay slurry and the trunks were wrapped in paper. This time there was no cause for shock to the trees because they were extracted whole without any further root pruning. It is possible that if such an operation were conducted in the middle of the rainy season one could dispense with wrapping the trees.

(*Received January, 1959*)

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* FX clones are South American Leaf Blight-resistant clones developed at Ford Rubber Plantations in Brazil.

Experiments on the Germination of Banana Seeds

N. W. Simmonds

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In this paper the results of twelve experiments on factors influencing the germination of banana seeds are described. These experiments are an extension of an earlier series reported some years ago in this journal (Simmonds, 1952). For convenience in reference, all the experiments are numbered serially, I to XV having been described previously, XVI to XXVII in the present paper.

METHODS

Earlier work (Experiment XIV) having shown that six-inch clay pots filled with river sand provide a satisfactory medium for germination, all the present experiments were carried out in such pots, with the exception of XXVII for which boxes of greenhouse soil were used. Germination was recorded at intervals (usually once or twice weekly) until no further increase was noted. Samples of 50 seeds were used in each instance. Analyses of variance were carried out after angular transformation of the raw data. The significance of variance ratios is indicated by means of the following conventions: ***—0·1 per cent; **—1 per cent; *—5 per cent. The relevant numbers of degrees of freedom (n_1, n_2) are given in parentheses. As in the earlier work, variances were found generally to exceed the theoretical value of 16; the average of 19 error mean squares weighted by degrees of freedom was 40·2.

RESULTS

(a) *Germination and early seedling growth*

The germination of a banana seed has not been previously described and it is therefore useful to give a brief account here. Humphrey (1896) comments on the comparative morphology of the seeds of Scitamineae and Boyd (1932) gives a general account of the germination of monocotyledonous seeds; neither author, however, makes more than passing reference to *Musa*.

The first visible sign of germination is the exudation from the micropyle of a drop of brownish fluid. The micropylar lid is then extruded and the primary root emerges. The lid is truncate-conical in shape and it comes out cleanly, the tapering outside face of separation from the body of the testa being smooth and polished and evidently a line of predetermined breakage. The primary root springs from an irregularly swollen hypocotyl on which adventitious roots and the aerial shoot are differentiated [*Figure 1* (a), (b)].

In a week from the beginning of germination, the adventitious roots have overtaken the primary root in growth and the plumule has become prominent; in two to three weeks the primary root is hardly identifiable as such, the plant consisting, in effect, of a prominent shoot which bears at its base an

adventitious root system and the remnants of the seed. The first two leaves are represented by bladeless sheaths; the third, which is produced about two or three weeks after the beginning of germination, bears an expanded blade [*Figure 1* (c)].

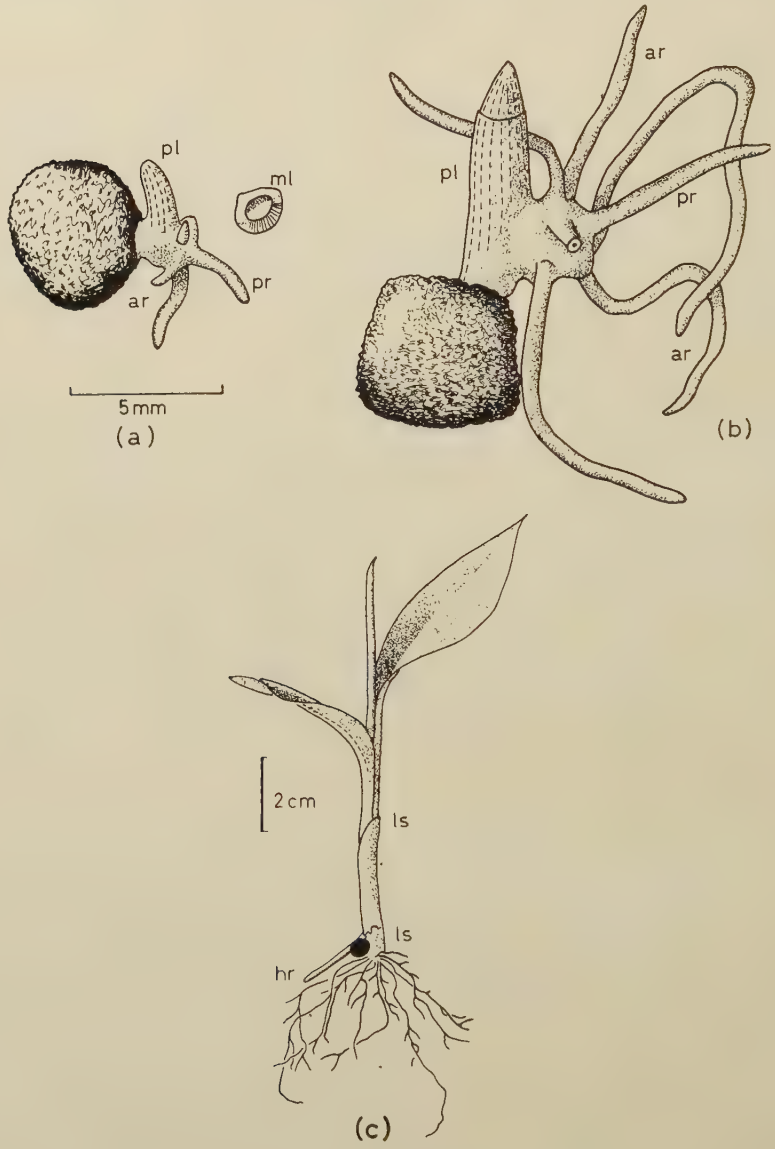

Figure 1. Three stages in the germination of a banana seed (Musa balbisiana). (a)—*about three days after the start, primary root still prominent;* (b)—*about a week after the start, adventitious roots dominant, plumule exceeding collar, second leaf visible (not in posture of life—root system arranged for drawing);* (c)—*about four weeks old, two leafless sheaths, two expanded leaves and one rolled leaf visible, first member of new system of strong horizontal adventitious roots present.* [*Abbreviations: pl—plumule; pr—primary root; ar—adventitious roots; cl—collar; ml—micropylar lid; ls—leafless sheath; hr—horizontal root*]

In about four weeks, seedlings grown in sand show evident signs of malnutrition and are by then presumably dependent on the roots for their mineral nutrients. All visible traces of endosperm disappear from the seed within two weeks of the beginning of germination but the testa and haustorium persist for at least five weeks and often more before they are detached or rot.

The root system of the young seedling is composed of slender, mostly descending, somewhat branched, adventitious roots. At about one month of age a new type of root suddenly appears and swiftly replaces the juvenile system; the new type of root is markedly thicker, longer and less branched than the juvenile type. It is borne higher on the stem than the juvenile type and it pursues a horizontal or but slightly descending course in the soil. The new type of root appears without transition and is the first indication of the form that the mature root system is later to take [*Figure 1* (c)].

It is worth noting in passing that some related plants show somewhat different germination behaviours (*Figure 2*). Thus, of three Trinidad

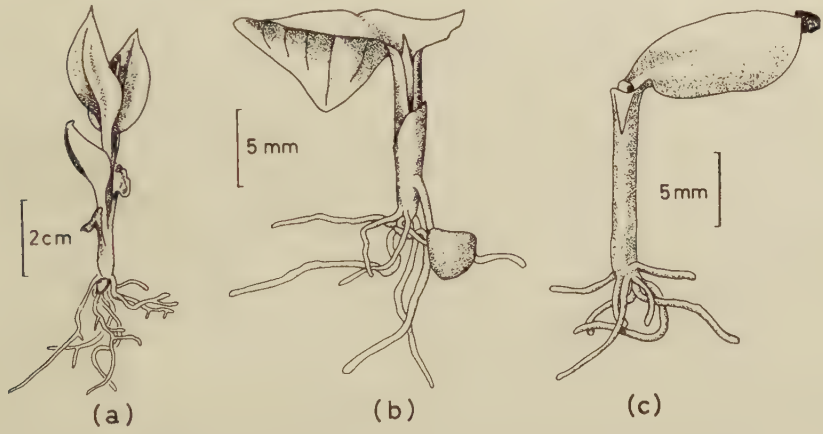

Figure 2. Seedlings of three Trinidad Zingiberaceae. (a)—Hedychium coronarium; (b)—Renealmia exaltata; (c)—Costus cylindricus

Zingiberaceae, one (*Hedychium coronarium*) was morphologically similar to *Musa*; one (*Renealmia exaltata*) also germinated hypogeally but developed a considerable stalk between the seed and the area of outgrowth of the plumule; and the third (*Costus cylindricus*) germinated epigeally, the testa being carried above ground at the tip of the first leaf and later shed. *Musa*, *Hedychium* and *Renealmia* belong to Boyd's (1932) Type C, *Costus* to Type A.

(b) *Experiments on greenhouse and collecting technique*

Experiment XVI—Musa balbisiana. There were four treatments, each four times replicated. The treatments were: control, seeds extracted from normally ripened fruits; seeds extracted from mature but unripe fruits which had been dried in the oven for four days at 45°C (113°F); seeds extracted from ripe fruits similarly dried in the oven; seeds extracted from over-ripe fruits similarly dried in the oven. All the fruits on which this

experiment was based were taken randomly from a mature but unripe bunch of *Musa balbisiana.*

The temperature adopted for this experiment (45°C) was chosen as a probable temperature attained by fruits directly exposed to full tropical sunlight on a dark surface. Measurements showed that, on a bright day in Trinidad, single fruits protected from wind and covered with a sheet of glass attained precisely this temperature, air temperature at the same time being 28° to 30°C. Unprotected fruits attained 38° to 39°C. Correspondingly higher temperatures would presumably be attained in hotter climates.

Table 1. Experiment XVI—the effect of drying whole fruits

Treatment	*Germination per cent*	*Days to 50% germination*
Control (C)	27·5	34·5
Green (G)	25·3	60·3
Ripe (R)	69·0	30·5
Over-ripe (O)	63·5	22·5
V.R. (3, 11)	16·2***	10·8***
Conclusions	$C, G \ll R, O$	$C, R, O \ll G$

Results are shown in *Table 1*; the rapid drying of whole fruits did not impair viability—indeed, seeds extracted from fruits dried ripe and over-ripe germinated significantly better than control batches which were themselves, however, much less viable than is normally expected of material of this nature. Rate of germination was also affected by the treatments and was roughly correlated with viability, the higher the germination the faster.

The experiment was performed in the hope that a rapid means of preserving viability of freshly collected banana seeds could be achieved for use in emergencies when ordinary methods of extraction could not be adopted. The results show that drying of whole green fruits could in fact be used (though suitable weather would not commonly be encountered). If the fruits are ripe, the seeds are quite easily extracted and there is no practical advantage to be gained from drying whole fruits though the experiment shows that it can safely be done.

The germination of control batches in this experiment was poor both in relation to general experience with *Musa balbisiana* and to the germination of batches extracted from dried ripe and over-ripe fruits. The reason for this is unknown.

Experiment XVII—Musa balbisiana. There were fifteen treatments, each replicated once. Seeds were stored for two, four and eight weeks in various quantities of dry charcoal. The quantities of charcoal used were: nil, trace (seeds dusted with charcoal and roughly picked clean), and twice, four times and eight times as much charcoal as seeds (by weight). All samples were prepared from freshly harvested moist seeds and each was enclosed in a sealed polyethylene bag. The bags were stored in the dark because an earlier experiment (VI) had shown that light was deleterious to seeds under moist storage.

Results are summarized in *Table 2.* Analysis shows that all charcoal treatments were deleterious and that there was a significant decline in

viability over the period of the experiment. This experiment was performed because some banana seed collections from the East have been received in charcoal and because such packing is regularly used in sending seeds of some other plants (e.g. cocoa) on long journeys; it was therefore thought

Table 2. Experiment XVII—the effect of charcoal during moist storage

Amount of charcoal	*Germination per cent after weeks of storage*			*Means*
	2	4	8	
Nil	86	68	59	71·0
Trace	53	36	40	43·0
2×	69	38	58	55·0
4×	60	39	49	49·3
8×	66	47	55	56·0
Means	66·8	45·6	52·2	—

Analysis: V.R.—charcoal (4,15) = 4·99**; storage time (2,15) = 8·54**; interaction negligible. Conclusions: 2 weeks > other storage times; nil > all other charcoal treatments.

possible that it might be of use with bananas when circumstances demanded rapid packing and despatch of fresh moist seeds. This is evidently not so, however, and it looks as though the use of charcoal for storing banana seeds should be avoided.

Experiment XVIII—Musa balbisiana. There were three treatments each five times replicated. The treatments were: control; BHC dust (0·5 per cent gamma-isomer) applied twice weekly to the pots; DDT dust (5 per cent) also applied twice weekly. A 'large pinch' of dust (*ca.* 2·3 g) was applied on each occasion to each pot. For the BHC treatment this was equivalent to the application of 4 × 2·3/50 = 0·18 g dust per seed (about 1 mg of the gamma-BHC) up to the time at which germination began. The

Table 3. Experiment XVIII—the effect of insecticides on germination

Treatment	*Germination per cent**
Control	77·6
BHC	2·0
DDT	78·4

* Appearance above surface of sand.

results are shown in *Table 3.* Evidently BHC is highly deleterious whereas DDT is not. Examination of treated seeds at a time when the shoots of germinated control seeds had appeared above the sand surface showed that BHC did not appreciably inhibit germination; instead, it stopped growth immediately afterwards, the effect being most conspicuous on the roots, which were short, thickened and malformed. Normal seedlings in the two-leaf stage transferred to BHC-treated pots ceased to grow and after a fortnight bore stunted roots of which the longest were only 2 cm in length; roots of control plants were then 7 to 12 cm long.

According to K. Shepherd (personal communication) the mitotic chromosomes of roots of treated plants showed the same signs that characterize

overtreatment with such mitotic poisons as paradichlorbenzene, α-bromonaphthalene and oxyquinoline. Similar cytological effects of BHC in various plants have been recorded by D'Amato (1949, 1950).

This experiment was undertaken because casual observations in the greenhouse on pots and boxes treated with BHC dust as a measure against leaf cutting insects had suggested that this insecticide inhibited germination (or early seedling growth). A similar (though less drastic) effect on seedling growth has been recorded for tobacco by Ashby (1950). Evidently BHC may be less generally suitable for seed treatment than is commonly assumed.

(c) *Experiments on seed ecology*

Experiment XIX—Musa balbisiana and *Musa acuminata.* There were twelve treatments each three times replicated. The treatments were: *Musa balbisiana* seeds stored for six, nine and twelve months, *Musa acuminata* seeds for nine months only; seeds were stored at three depths in the soil, namely just under the surface and at one and two feet below the surface. Seeds were mixed with moist sand and the mixture packed tightly into porous porcelain pots. The pots were buried at the appropriate depth in a trench dug in a grass lawn. The scar was grassed over and the site mown in the usual fashion until the trench was reopened to retrieve samples for test.

Results are shown in *Table 4.* Viability was maintained virtually constantly over the period of the experiment but there was a big effect of depth of storage, surface burial being much inferior to deep burial.

Table 4. Experiment XIX—storage in soil

Depth (feet)	*Germination per cent after various periods of storage*				
	Musa balbisiana				M. acuminata
	6 *months*	9 *months*	12 *months*	*Means*	9 *months*
0	14·0	8·0	11·3	11·1	3·3
1	14·0	22·7	20·7	19·1	48·0
2	18·7	16·7	18·7	18·0	42·7
Means	15·6	15·8	16·9	—	—

Analysis (*balbisiana* results only): V.R. Times (2,18) < 1; Depths (2,18) $= 7{\cdot}69^{**}$; interaction D × T (4,18) = 2·14. Conclusions: 0 < 1 and 2 feet, the effect consistent over the three periods of storage.

This experiment was carried out because casual observations in the lands of the Botany Department of the Imperial College of Tropical Agriculture had suggested that buried banana seeds retained viability for a surprisingly long time—in one instance the history of the site suggested a period of two or three years. The results show that, so long as the seeds are reasonably deeply buried, a relatively high degree of viability is retained for at least a year.

Experiments XX to XXII—Musa acuminata and *Musa balbisiana.* All three experiments consisted essentially of storing moist seed samples in sealed jars in the dark, the atmosphere of each jar being adjusted to a known initial carbon dioxide concentration at the start of the experiment. In some instances (A in *Table 5*) the initial atmosphere was air. Kilner jars were used for storage. Carbon dioxide was generated by the addition of the requisite volume of standard hydrochloric acid to excess calcium carbonate

placed in a glass container inside the jar; immediately after adding the acid, the lid was replaced lightly and the jar sealed as soon as visible bubbling had ceased. Zero carbon dioxide concentration was achieved by placing a few pellets of sodium hydroxide in the internal container. Seed samples were sewn into light muslin bags or, in one experiment, placed in the jars in specimen tubes. A third container in each jar contained water so that the atmosphere should remain constantly saturated. In one experiment (XXI) the seeds were treated with an organic mercurial fungicide before the beginning of the experiment.

Results are summarized in *Table 5*. No very detailed conclusions can be drawn from them but there is a distinct indication that viability was best maintained in the jars which had an initial carbon dioxide concentration in the range 2 to 10 per cent. It should be emphasized that control was

Table 5. Experiments XX to XXII—storage in sealed containers with various initial carbon dioxide concentrations (A—air)

Expt	*Time*	*Species*	*Germination after storage in initial carbon dioxide concentration (%)*												
			0	A	1	2	4	5	8	10	16	32	50	64	100
XX	6 *months*	acuminata	28	6	0	—	—	84	—	—	—	—	8	—	0
		balbisiana	28	4	0	—	—	86	—	—	—	—	62	—	0
XXI	6 *months*	acuminata	0	0	—	—	—	3	—	0	—	—	0	—	0
		balbisiana	53	66	—	—	—	75	—	71	—	—	66	—	11
XXII	12 *months*	acuminata	0	—	—	34	32	—	0	—	0	0	—	14	0
		balbisiana	0	—	—	24	14	—	0	—	0	0	—	4	0

exercised only over the initial gas concentration, not at all over the subsequent changes caused by respiration of the seeds themselves or over the effects of the metabolism of micro-organisms. On opening the jars it was evident that some germination and subsequent rotting had occurred; it was evident also from odours and inspection of the seeds that there had been considerable micro-organic activity—this even in Experiment XXI which had received a fungicidal treatment.

These experiments were carried out because of the possibility that carbon dioxide concentration might be an important factor in maintaining viability of seeds buried in the soil. The results, as far as they go, provide some indication that viability is best preserved at fairly low concentrations but it should be emphasized that extensive experimentation involving the use of continuously flowing controlled atmospheres would be necessary to put the matter on a rigorous basis.

Experiment XXIII—Musa balbisiana. There were fifteen treatments, unreplicated. Seeds contained in muslin bags were dipped in alcohol and then treated with mercuric chloride at three different concentrations (0·01, 0·001 and 0·0001) for five different periods of time (0, 1, 5, 10 and 30 minutes); samples were then swiftly dipped in alcohol once more and washed in several successive batches of sterile water. Seeds were planted in

pots of formalin-sterilized soil in the greenhouse after which no further attempt was made to maintain sterility. Parallel samples of ten seeds each were treated identically and sown in Petri dishes of nutrient agar in the laboratory.

Results are summarized in *Table 6*. Using the product time × concentration as a measure of intensity of treatment with mercuric chloride, correla-

Table 6. Experiment XXIII—sterilization of seeds and its effects on viability, rate of germination and surface contamination by micro-organisms

Treatment†	*Germination per cent*	*Rate (days to 50% germ.)*	*Contamination per cent*
0	78	17	100
0	64	19	100
0	70	19	100
1	56	18	80
5	72	25	70
10	74	21	60
10	76	23	70
30	64	21	50
50	54	25	20
100	74	19	30
100	60	25	30
300	50	28	0
500	54	26	20
1000	58	26	0
3000	42	42	0
r‡	−0·59*	+0·72**	−0·94***

Notes: † Treatment is the product of time (minutes) by concentration of mercuric chloride × 10 000; ‡ the correlations in the bottom line are of the three variates with log treatment, zero treatments being omitted ($n = 12-2 = 10$).

tion analysis of the logarithm of this product with germination per cent, rate of germination and contamination in the laboratory series shows that: germination was progressively reduced and delayed by the treatment and that contamination by micro-organisms was reduced from 100 per cent in the control (time 0) treatments to zero in the most severe treatments. Observations of the agar plates suggested that bacteria survived only the lightest treatments (0, 1 and 5 in *Table 6*) but that fungi were much more persistent. In particular, an *Aspergillus* persisted through most of the more intense treatments; it was observed characteristically growing from the micropyle of the seeds where, presumably, it had been protected from the sterilizing agents by being confined to minute fissures at the edge of the micropylar lid.

Experiments XXIV and XXV—Musa balbisiana. In Experiment XXIV there were six treatments, each five times replicated. The treatments were: control; alcohol wash only followed by sterile water; and four combinations of mercuric chloride treatments (concentrations of 0·001 and 0·01 each for one and fifty minutes). Experiment XXV was similar except that it had eight treatments, the same as those of Experiment XXIV *plus* two 10-minute mercuric chloride treatments.

Results are summarized in *Table 7*. The two experiments apparently contradicted each other for in the one (XXIV) the control samples germinated the best (significantly better than all other treatments except one)

Table 7. Experiments XXIV and XXV—sterilization of seeds with mercuric chloride

Treatment		XXIV Germination per cent	XXIV Rate of germination (days)	XXV Germination per cent	XXV Rate of germination (days)
1. Control		63·2	16·4	25·6	55·0
2. Alcohol		40·4	20·8	50·8	36·4
3. 0·0001	*1 min*	40·4	18·8	48·8	32·6
4.	*10 min*	—	—	30·8	34·8
5.	*50 min*	57·6	17·8	34·8	34·4
6. 0·01	*1 min*	42·4	20·4	40·0	42·4
7.	*10 min*	—	—	28·4	37·6
8.	*50 min*	23·6	30·8	38·0	32·4
V.R. (n_1, n_2)		11·8***(5, 24)	34·7***(5, 24)	3·3**(7, 32)	15·1***(7, 32)
Conclusions		1, 5 > 2, 3, 6 > 8	8 > *others*	*No grouping*	1 > *others*

whereas in the other (XXV) the control samples germinated worst (significantly worse than three out of the seven other treatments). Rate of germination was roughly related to viability but it will be noted that, similar as the two experiments were, rates were on the whole much lower in Experiment XXV than in Experiment XXIV. It will be noted that in both experiments, seeds subjected to a brief alcohol dip differed significantly from the controls in respect of both germination percentage and rate of germination, the treatment producing lower and slower germination in one experiment (XXIV) and faster and higher germination in the other (XXV).

Experiment XXVI—Musa acuminata and *Musa balbisiana.* There were 21 treatments, each five times replicated. Seed from seven different banana clones (four of *Musa acuminata* and three of *M. balbisiana*—see *Table 8*) were used; seeds were extracted from ripe bunches and cleaned, washed and dried in the usual way. Three treatments were applied to batches from each of the seven clones: control, alcohol dip followed by sterile water and alcohol dip followed by five minutes immersion in 0·0001 mercuric chloride followed by repeated washing.

Table 8. Experiment XXVI—sterilization in relation to botanical origins

Source of seed: Species	Clone	Germination per cent: Control (1)	Alcohol (2)	Mercuric chloride (3)	Results
acuminata	*ssp.* burmannica				
	Long Tavoy	52	26	24	1 > 2, 3
	Calcutta 4	71	68	63	± *equal*
	ssp. siamea				
	Annam	95	89	87	± *equal*
	ssp. malaccensis				
	Langet B	43	5	3	1 > 2, 3
balbisiana	*Cliffortiana*	63	22	20	1 > 2, 3
	Yella bale	53	61	86	3 > 2, 1
	Butuhan	49	78	80	2, 3 > 1

Results are summarized in *Table 8* where it will be seen that the inconsistencies as between batches of seed from different sources that were revealed by the two preceding experiments (XXIV, XXV) are substantiated. In three samples, sterilization (whether by alcohol alone or by alcohol and mercuric chloride) caused a marked drop in viability; in two experiments, sterilization caused a rise in viability and in the remaining two it had little or no effect.

Experiment XXVII—Musa acuminata and *M. balbisiana.* There were eight treatments, seeds of each of the two species being subjected to four treatments: (*1*) control (seed air-dried and held for eight days in the laboratory until the animal-fed batches were ready for sowing); (*2*) whole fruits fed to pigs whose droppings were searched for three days and the banana seeds extracted and counted; (*3*) seeds fed (as clean wet seeds) to fowls whose droppings were searched for seven days, at the end of which time (*4*) the birds were killed and the residual seeds in their gizzards extracted and counted.

Results are shown in *Table 9.* First, it seems that the two banana species survived differentially in the two animals, *acuminata* surviving better in the

Table 9. Experiment XXVII—animal feeding experiment

Treatment	*Seeds fed*	*Seeds recovered*	*Per cent recovery*	*Seeds sown*	*Germ'n per cent*	T_{50}§	*Survival per cent*
M. acuminata							
Pig-droppings	1909†	145	7·6	2 × 50 + 45	45·3	22·7	3·5
Fowl-droppings	466‡	18	3·9	18	0	—	0
Fowl-gizzard		131	28·1	2 × 50 + 31	0	—	
Control	—	—	—	5 × 50	58·4	20·8	—
M. balbisiana							
Pig-droppings	6616†	1603	24·2	5 × 50	39·2	22·8	9·5
Fowl-droppings	2113‡	115	5·5	2 × 57	1·8	—	0·3
Fowl-gizzard		123	5·8	2 × 50 + 23	4·1		
Control	—	—	—	5 × 50	44·0	28·4	—

Notes: † fed as whole ripe fruits, seed contents estimated;
‡ fed as seeds, actually counted (see text);
§ time (days) to 50 per cent of final germination.

fowls than *balbisiana*, *balbisiana* better in the pigs. These results, being unreplicated, are not susceptible of analysis, however. Many broken fragments of seeds were recognized in the pig droppings. The seeds of both species recovered from the fowls were all somewhat polished by the action of stones in the birds' gizzards. The two animals had markedly different effects on viability, seeds consumed by fowls giving uniformly low germination, those consumed by pigs being, at most, slightly (non-significantly) less viable than the controls [V.R. (1,14) = 1·29]*. The difference between species is also non-significant [V.R. (1,14) = 2·18] and the interaction, species × treatment, is negligible [V.R. (1,14) = 0·28]. The only marked effect on rate of germination revealed by the experiment was in *M. balbisiana* in which seeds consumed by pigs germinated more rapidly than the controls; the first germinations in the two groups differed in time by seven days and the average difference in time to 50 per cent germination was 5·6 days in favour of the seeds eaten by pigs [t (14) = 4·3***]. Other differences in rates of germination were non-significant. Associated with this difference in rate of germination was a difference in the shapes of the germination/time curves; control curves were sigmoid in shape, curves for treated seeds

* The analysis was performed on pig and control data only, giving a 2 × 2 classification; allowance was made for non-orthogonality.

convex or more or less linear up to the point of maximum germination (*Figure 3*). The same tendency was apparent in *Musa acuminata*.

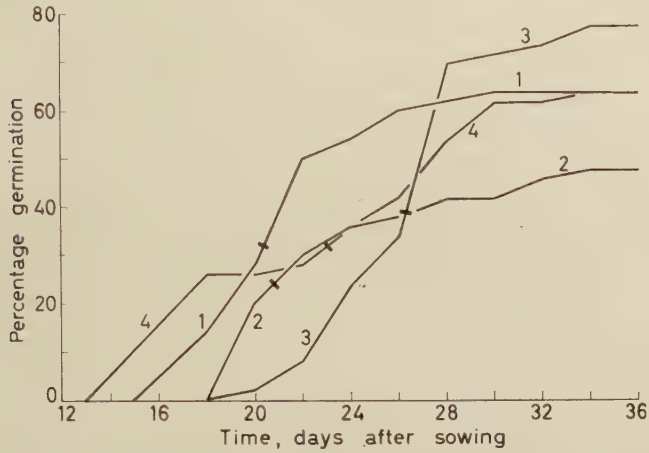

Figure 3. Germination curves from Expt XXVII. 1—M. acuminata, *control; 2*—M. acuminata *after passage through pig; 3*—M. balbisiana, *control; 4*—M. balbisiana *after passage through pig. The cross-bar on each curve marks the point of 50% final germination* (T_{50}). *The four curves were arbitrarily selected from the eighteen available by taking from each of the four groups of replicates the plot which gave the highest final germination*

The general conclusion from the experiment is that overall rate of survival in the two chosen animals is low. The fowl destroys seeds mechanically and renders inviable most of those that survive; the pig is less destructive than the fowl and surviving seeds are virtually unaffected as to viability. The pig also has certain, not interpreted as yet, effects on seed behaviour as evidenced by accelerated germination in one species and altered form of the germination/time curves.

DISCUSSION

Jointly, the experiments on banana seeds that have been described indicate that the highest germination is obtained from seeds extracted from ripe fruits, cleaned and sown immediately or, if a period of storage is necessary, from seed similarly extracted and cleaned and then dried. Any departure from this practice—as, for example, the extraction of immature seed or seed from rotting fruits or storage in moist or dirty condition—tends to cause loss of viability, often severe loss. There is no evidence that seeds of the two species (*Musa acuminata* and *M. balbisiana*) that were used in these experiments ever undergo a period of dormancy. Sometimes, however, a sample of seed which is known to have been well prepared gives low or nil germination and the possibility exists that an erratic dormancy mechanism is at work. This sort of behaviour is more conspicuous in some other members of the family, notably in *Ensete*, in which germination, even of well prepared samples, is markedly erratic. It is possible, therefore, that different species differ in seed behaviour and it would certainly be unwise to assume that the group is uniform in this respect.

Experiments XVI and XVII prompt no significant modification of established practice in dealing with banana seeds. They show that, in emergency, whole fruits may be dried and some viability retained; that charcoal is deleterious to the viability of moist seeds under short periods of storage and that the use of BHC is to be avoided in the banana greenhouse.

Ecological aspects of the experiments are best treated under two headings, namely: the conditions necessary for maintenance of viability in soil and the implications of experiments on sterilization. The effect of storage in soil can best be considered in comparison with the results of two other treatments. Experiment X showed that seeds stored in the open air lost nearly all viability in a year; the same seeds stored in soil would retain a significant degree of viability during the same period of time (XIX); and the same seeds sown in a seed box soon after harvest would give a high germination in about a month.

Evidently, there is some feature of the soil environment that tends to preserve viability of moist banana seeds. Experiments XX to XXII, though irregular, jointly suggest that carbon dioxide concentration is concerned in the problem. In a review of investigations of seed physiology, CROCKER and BARTON (1953, pp 76, 115, 122) drew attention to the fact that moderate concentrations (about 10 per cent) of carbon dioxide inhibited respiration of certain seeds and that various experiments had indicated that carbon dioxide–oxygen relationships were probably responsible for the preservation of viability of various seeds in moist storage, conspicuously in soil. It has, of course, long been known that many seeds survive for very long periods in soil, data of the order of 20 years for certain temperate plants being not uncommon (see OWEN, 1956, for a general review of longevity of seeds).

Experiments XX to XXII indicate 2 to 10 per cent carbon dioxide as the most favourable initial concentration for the preservation of viability of moist banana seeds in sealed containers. The final concentrations of carbon dioxide achieved in these experiments is not known—they must have been considerably higher than the initial concentrations. It seems significant that these data correspond reasonably well with carbon dioxide concentrations recorded in the soil atmosphere of certain tropical soils. For example MOHR (1944), citing the early work of Leather in India, gives the following data for arable land: carbon dioxide 5 to 17 per cent, oxygen 2 to 14 per cent by volume. In the soils of Trinidad cacao fields, VINE, THOMPSON and HARDY (1942) found that aeration and composition of the soil atmosphere varied with site, depth and season; average data for four soils, five depths and two seasons (wet and dry) were: carbon dioxide 4·8 per cent (range 0·5 to 17·5 per cent), oxygen 15·2 per cent (range 3·1 to 20·8 per cent). As a working hypothesis, therefore, it seems reasonable to suppose that the preservation of viability of banana seeds in soil is at least partly dependent upon the composition of the soil atmosphere.

The most striking result of the experiments on sterilization (XXIII to XXVI) is the variability of reaction of different batches of seeds. Presumably, three factors are involved: first, a direct adverse effect of the sterilizing agents on viability, that is toxicity; secondly, the killing of micro-organisms responsible for the encouragement of germination; and, thirdly, the killing of pathogenic micro-organisms. The first and second effects cannot yet be

formally distinguished. However, the fact that some sterilized samples (e.g. Experiment XXVI, lines 3, 6 and 7 of *Table 8*) gave high germinations suggest that the direct toxicity effect is not serious, at least at moderate concentrations of mercuric chloride. If this is generally true, then the experiments seem to provide evidence that both favourable and pathogenic organisms were sometimes present. The system is obviously very complex and only to be analysed by isolation and testing of individual micro-organisms.

It is convenient finally to present a brief review* of banana seed ecology. The normal fate of a wild banana fruit is to be eaten by an animal; in the field one very rarely sees a ripe or fallen bunch because the fingers are attacked as soon as they start to turn colour. They are rarely (indeed, in the writer's experience never) attacked in the hard green condition and it may be that the astringency of the unripe fruit makes them unpalatable enough to deter animals from attacking them. The animals responsible have not been systematically recorded; presumably, bats, birds and monkeys are the most important. In India, wild species of *Musa* and, in East Africa, wild species of *Ensete* are attacked by elephants which, however, are more interested in the foliage than in the fruit. Experiment XXVII shows that banana seeds can pass unharmed through at least one animal, the pig, though the overall rate of survival is low. It would be interesting to have similar information for the wild animals that eat banana seeds.

Figure 4. Gregarious germination of banana seedlings on land cleared and fired from second growth at Dagua, Sepik District of New Guinea, 7.12.54. Probably Musa schizocarpa *and/or* M. acuminata *ssp.* banksii

* A few new observations are included in the following paragraphs.

Figure 5. Gregarious growth of seedlings of Musa erecta *by the Busu River near Lae, New Guinea, on land disturbed by logging, 2.1.55*

However dispersed, banana seeds can remain dormant in soil for fairly long periods, certainly for a year (XIX) and probably for longer. The indications are that seeds of *Ensete* survive for longer periods in the soil (up to 25 years—BAKER and SIMMONDS, 1953) than seeds of species of *Musa*. Presumably the majority of banana seeds dropped by animals remain in the soil surface, germinate and die. The writer has seen good examples of such scattered germinations in high forest in Queensland where small seedlings of *Musa acuminata* subsp. *banksii* were not infrequently encountered in situations in which survival was impossible. Seeds which survive in the soil in a viable state germinate when the site is disturbed—as in the cultivations at the Imperial College of Tropical Agriculture referred to above and as is not infrequently seen in sites newly cleared from bush in southeast Asia and the Pacific. A striking example of the latter was noted near Dagua in the Sepik District of New Guinea, a patch of land cleared and fired for garden planting being carpeted locally with what can only be described as a sward of banana seedlings (*Figure 4*). Another example of a disturbance that provides buried seeds with suitable conditions for germination is a landslip and the writer has seen banana seedlings in such places in Samoa. The final result of any disturbance is commonly a more or less gregarious germination that reflects an intense seed rain in the past and the localized occurrence of conditions suitable for the preservation of viability.

Some rough calculations will give an idea of the magnitude of the seed rain just mentioned. In disturbed second growth on volcanic hill slopes in Samoa, rough visual estimates indicated the presence of about 20 banana

plants per acre on the average over considerable areas. If each produced one bunch per acre per annum and each bunch bore 100 fruits each with 80 seeds, the seed rain would be about 40 per square metre per annum; at the upper limit, the rain might be as high as about 160 per square metre per annum (3 bunches per stool, 120 fruits per bunch, 90 seeds per fruit). These amounts are necessarily very rough but it is obvious that a low rate of survival would suffice to explain the occurrence of comparatively dense stands of young plants in subsequent years (say, one plant per ten square metres—see *Figure 5*). Exceptionally dense stands (many seedlings per square metre—*Figure 4*) are probably the result of the occasional falling of whole bunches uneaten by animals or perhaps of the presence of a bat colony in an overhanging tree.

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A System of Maximum Multiplication of the Banana Plant

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The nature of the banana plant has made it imperative that reproduction be accomplished by vegetative means since most commercially grown bananas are vegetatively parthenocarpic and effectively seed-sterile (Baker and Simmonds, 1951). In Central American cultivations it has been the custom to plant large rhizome pieces on the supposition that initial growth would be more rapid with such large pieces, thereby permitting the earliest possible cropping. On the other hand, much smaller ' seed ' are employed in Australia (Wills and Berrill, 1953) and in South Africa (Malan, 1949). Recently, in Central America, there have arisen occasions when the requirement for early cropping has been subordinate to a need for the most rapid possible increase in total plants. This has led to an evaluation of the available reproductive materials, including the planting of small seed to attain the desired increase in total plants.

A maximum of available plants can be obtained by carefully splitting the rhizome to take advantage of every viable bud or ' eye '. The greatest efficiency with this method (Anon., 1955) was obtained when rhizomes from plants with a basal diameter of 20 to 25 cm were split horizontally and planted in a multiplier (Vallaeys, 1952) under nursery conditions. The resulting 14·2 shoots per originating rhizome were planted out when 30 to 40 cm high. When these shoots grew to a basal diameter of 20 to 25 cm, the process was repeated. The total number of plants thus obtained was high, 14·2 from 1·0, but the system requires specialized installations and handling.

That a greater potential maximum increase exists than by any method yet described becomes evident when the morphology of the banana plant is considered. The so-called (Skutch, 1932; Esau, 1935) ' axillary ' buds that in the normal course of events never attain any degree of development in the banana plant might well serve as seed. To determine the feasibility of this scheme, the research described herein was performed.

MATERIALS AND METHODS

The banana plant initiates growth from a bud in a basal, bulky rhizome and forms a short true stem from which the buds, arranged in an ascending spiral, grow. Their tightly appressed, clasping leaf bases form the apparent or ' pseudo ' stem. The length of these sheathing leaf bases may approach 20 ft, although the true stem of the vegetative plant rarely exceeds 18 in., *Figure 1*. On this true stem, lateral buds are to be found where the edges of

* A subsidiary of the United Fruit Company.

Figure 1. True stem of a banana plant. Note the apical growing point; circular, dark leaf insertion scars; spirally arranged buds; and cut older sucker

Figure 2. Position of a lateral bud on the true stem within the two edges of a single leaf base

each leaf base meet to form a V, *Figure 2*. These buds may be in an advanced stage of development when associated with an older outer leaf, or may be rudimentary when associated with one of the younger inner leaves, *Figure 3*. As the banana plant matures, the older leaves cease to function, dry and fall off. The older buds thus exposed develop rapidly and become the suckers that must constantly be removed by pruning. The stage of development of the bud appears to be related to the degree of senescence of the associated leaf (SKUTCH, 1932). As the physiological age of the plant advances and the location of the bud becomes higher on the true stem (eventually above the the soil level) there is a marked change in its appearance. This is related to its development subsequent to exposure.

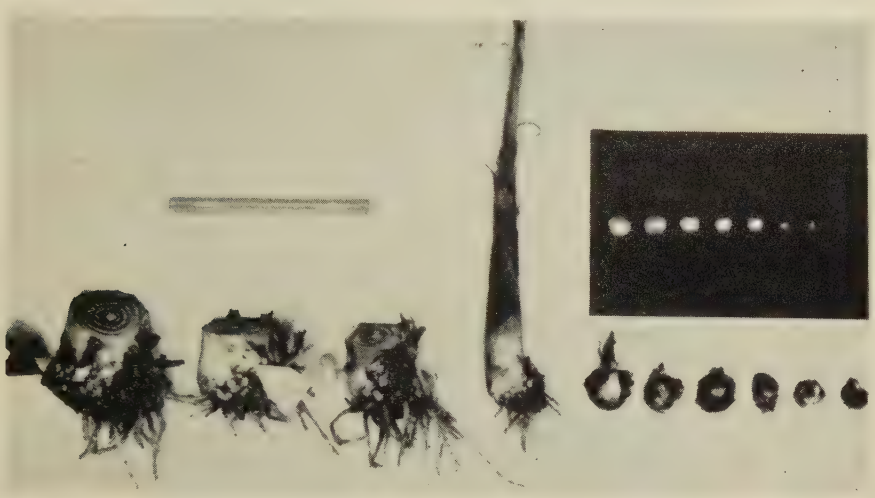

Figure 3. Stages of bud development on a single plant of five months. The three trimmed suckers (left) are plantable; those on the card are rudimentary and concealed by leaf bases

The early formed buds, those developing beneath the surface of the soil, develop in longitudinal axis to become suckers. Those formed later and positioned above the soil level do not develop strongly in their long axis but instead form onion-like protuberances on the true stem. These protuberances acquire a shaggy appearance through the drying away of unextended leaves and frequently exhibit a form of dormancy in that they do not grow with any frequency when cut off and planted. Such buds are seen for the most part on plants that have produced fruit. The reasons for this supposed dormancy, other than the unfortunate positioning, are under study.

In addition to these onion-like buds, often called ' buttons ', there are still a number of immature and unexposed buds associated with about 19 leaf bases that make up the pseudostem at the time the fruit is harvested. SKUTCH (1932) maintains that the leaves attached to the elongated axis of the fruited plant are not associated with buds. It is obvious that a number of these centrally located lateral buds never would develop into shoots even though they are potentially quite viable. The present report is concerned with the forcing of these buds, those laterally exposed, and those that never would be exposed.

PRELIMINARY EXPERIMENTS

In early studies all leaf sheaths were removed from plants five months old and over. This stimulated the growth of the larger of the exposed buds; unfortunately this effect was transitory and the buds ceased to grow after a brief burst of expansion. Three weeks after this treatment the rhizomes of the experimental plants were dug, split into as many pieces as there were obvious buds and these bits were planted. Most failed to develop into plants. Two rhizomes were left in the ground for three months after defoliating. When dug up, both were divided and the ten pieces thus derived were planted. Nine of these pieces germinated and grew vigorously.

Figure 4. Careful removal of a well developed sucker from the mother plant

Since it appeared that buds could not be forced too rapidly, a new series of experiments was initiated in which only a few buds were exposed at a time. These buds were covered with soil after the outer leaf sheaths and the older suckers were removed. All such buds grew vigorously, leading to the maximum propagation technique described in this paper.

MULTIPLICATION TECHNIQUE

The methods used are simple and can be carried out with a minimum of instruction and supervision. The original operation consists of removing the larger suckers that are to be the source for the projected increase. These plants should be five months old and growing vigorously. Following a

preliminary slight excavation of adjacent soil, suckers are harvested by cutting them free from the main pseudostem, *Figure 4*, using a narrow-bladed, sharpened shovel, square-tipped machete, or other similar tool. Care must be taken to avoid injury to the growing point located above and slightly to the side of the sucker being removed; this growing point will be the source of a later seed. It has been the practice to remove only suckers that are sturdy and have attained a height of 2 to 3 ft, for example over 1·5 lb when trimmed.

Figure 5. Splitting a cut leaf sheath prior to bud exposure

Subsequent to this original selection of suckers, soil is heaped carefully about the base of the treated plant and is packed down. Since in this first treatment more suckers are taken than in subsequent removals, damage to the plants may be extensive. It is possible that some ' burning ' of the leaves will follow this treatment. This will be most noticeable when water loss is extensive, for example, when the operation is performed in hot, dry, windy weather. The plant usually recovers with the development of new leaves. In addition to leaf burning, a large number of roots usually appear in the heaped soil about the base of the pseudostem. This is the plant's response to a damper and darker environment and, perhaps, to the wounding.

Seven days after the initial sucker removal, the first leaf sheaths should be stripped away to expose the basally associated but undeveloped buds. It is best not to expose more than three buds at a time, since those farther in will be only slightly developed. The last bud exposed should exceed thumb-nail size (2 cm^2), *Figure 2.*

The stripping operation is simple. The leaf sheath to be removed is pulled free of the pseudostem, cut off 4 ft above the ground, and split longitudinally down to the point of insertion, *Figure 5.* In turn, each half

Figure 6. Method of jerking the half leaf sheath free by tearing along the line of insertion

sheath is grasped firmly and, with a sideways and upwards jerk, is pulled free of the stem, *Figure 6.* Each exposed bud is ringed with a knife to form a plaque so that it will not be damaged with the removal of the next sheath. When the desired number of buds have been exposed, soil is heaped so as barely to cover them and they are left to develop. Hereafter leaf stripping and sucker removal are accomplished at the same time.

A second crop of suckers will be available after an additional week. Thereafter material can be removed and leaves stripped regularly depending upon growing conditions. A two-week cycle has been found convenient,

although every plant will not require attention fortnightly. Cropping can continue until it is apparent that no further shoots will appear. In agricultural practice, a single follower is allowed to develop undisturbed, after six weeks of complete sucker removal, to perpetuate the plant system that otherwise would become exhausted, *Figure 7.* The flower bud is also removed as soon as it appears, although saleable fruit has been obtained from stripped plants. Finally, it has been necessary to support the plants undergoing treatment, usually by means of strong bamboo props—otherwise, the weakened pseudostems would double over.

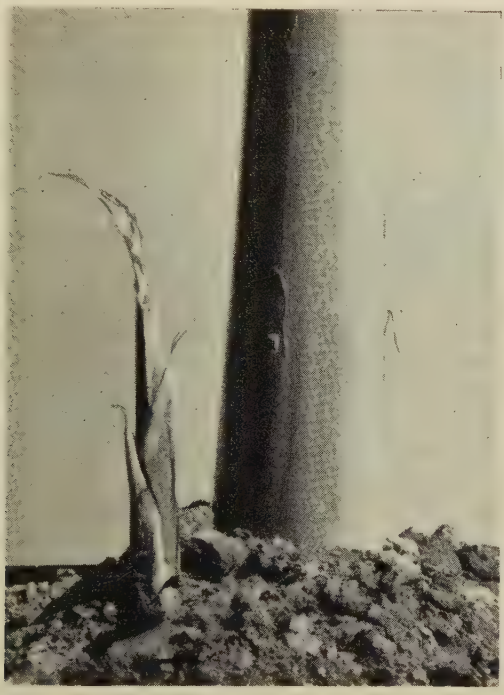

Figure 7. Stripped pseudostem. Note the soil heaped just above the topmost bud and the single follower

In one experiment, beginning with 25 plants each five months old, 514 suckers became available during the next six months. Twenty were lost in harvesting and, of those planted, 85 per cent survived. In addition, six months after the first sucker removal, the first planted progeny were ready to be stripped and had yielded 106 sucker ' seeds '. The increase, excluding the 106 from the progeny, was potentially 20·6 from 1. The survival rate was low because the first planting was followed by a three-day period of standing water due to excessive rainfall. The germination of 2 lb seed should approximate 93 per cent, *Table 1.*

In practical use by the Agricultural Department of the Tela Railroad Company, Honduras, over 2 500 plants were established within seven months of the first stripping and suckering of 123 original plants, with less

than 1 per cent loss by germination failure. The technique has been used on 11 varieties of banana.

The small seed requires some modification of the planting techniques used for bulkier seed pieces. If possible, suckers should be trimmed when harvested to within 1 in. of the apical meristem, *Figure 8*. It is advisable to plant small seed as soon as possible after harvesting, although a successful planting has followed a 21-day dry storage. It has been preferable to plant the small seed shallowly for maximum survival, although WILLS and BERRILL, 1953, recommend planting to 6 in. to foster deep rooting. With small seed the initial growth is extremely important, since a retarded plant can be rapidly shaded out in the intense vegetative competition of tropical growth. In

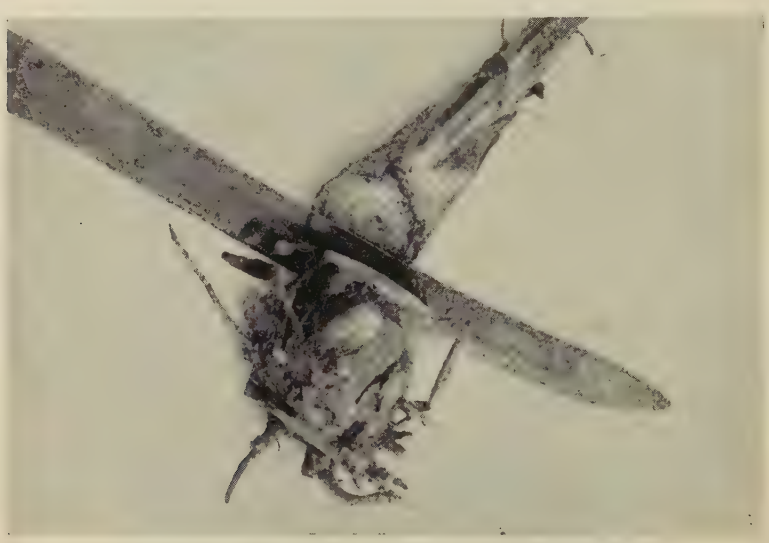

Figure 8. Sucker trimmed for planting. Root trimming and chemical treatment may be necessary in diseased areas

addition, soft rot can cause losses when the bud fails to grow out rapidly. Finally, sucker seed should weigh more than 1·5 lb when trimmed for planting. This is indicated in *Table 1*, where the relationships between seed weight and early growth and development are recorded. These data refer to growth from seed planted in Honduras in September 1958.

It is obvious that early growth in height is positively related to increased weight of seed from 1·0 lb up to 2·5 lb. It is indicated that for most purposes seed should exceed 2·0 lb for best performance in growth from the heart bud. Where rapidity of early growth is not of major importance, the initial weight of Gros Michel seed could be reduced to 1·5 lb. The monthly rate of increase tends to level off after 90 days when, presumably, the influence of an early vigorous growth imparted by the greater seed size ceases to be felt.

The planting of small seed should be followed as rapidly as possible by supply of water. Undue delay will seriously hinder the early growth of the plant. In addition, nitrogen should be supplied and, where applicable, other elements. In Central America nitrogen only is required and, as a

Table 1. Germination and growth in height of 100 sucker seed of each initial weight. Estimated monthly after planting

Initial weight (lb)	*No. of plants extant*		*Mean height (cm)*		
	30 days	*90 days*	*30 days*	*60 days*	*90 days*
0·5*	31	32	5·7	20·8	53·9
1·0	67	75	7·8	27·4	58·0
1·5	89	93	12·2	36·3	66·8
2·0	93	86	17·4	46·8	82·3
2·5	97	98	24·3	55·6	97·2
3·0	99	97	24·4	58·6	95·2
L.S.D. (0·05)†			2·69	5·20	8·35
(0·01)			3·54	6·99	11·02

* Not included in the analysis for growth.
† Least significant difference at 5 per cent and 1 per cent level.

common practice in banana plantings, used at 300 lb nitrogen/acre/year as urea. The first application of fertilizer should be made before the plants are three feet tall.

When these procedures are followed, sturdy plants should appear, growth should be vigorous, and a great increase in total number of plants can be expected within a relatively short period.

DISCUSSION

The simplicity of the technique described above makes it readily applicable within the banana industry, where involved processes frequently are difficult to use with the available labour force. No special seed beds are required and all planting is done in the open, with the one stipulation that water must be available when needed. As long as the seed is of good quality and size and is handled carefully, there need be few failures in germination.

It should be appreciated that the area to be planted will not immediately have an even stand, since the seed will become available in fortnightly increments. However, as stripping and suckering continue and a large population builds up, appreciable areas can be planted at the same time and raggedness will become less apparent.

This method should be of value whenever a new variety or sport is to be increased rapidly or when a new and isolated area is to be developed. From a few initial plants a sizable population can be established within a few years—possibly as rapidly as the land could be developed. Finally, when disease threatens or when movement of planting stock is restricted, the technique will permit a maximal means of expansion.

SUMMARY

A technique is described for the rapid multiplication of the banana plant. The method requires the digging and planting of all suckers when they have attained a trimmed weight of more than 1·5 lb, for example, and stand between two and three feet in height. In conjunction with this, the older leaf sheaths are stripped from the pseudostem, exposing the basally associated buds. These are covered with soil and left to develop. When a two-week routine of sucker removal and bud exposure is followed, approximately 20

plants can be obtained from the parent before the supply of lateral shoots is exhausted. Satisfactory germination and growth of the small seed will be obtained provided water is supplied as needed and the nutritional requirements of the plants met. The method has been used successfully in the field in Central America.

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A Note on Pruning of Bananas with 2, 4-Dichlorophenoxyacetic Acid

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When pruning of a banana mat is undertaken, the aim is to cut out the unwanted suckers or to kill them outright. The various mechanical procedures are well known. In Australia, the larger suckers may have their ' hearts ' gouged out (i.e. the apical growing point is destroyed) and kerosene or a mixture of kerosene and sump oil, in equal proportions, may be poured into the incision or cavity (Wills, 1951). Daudin (1955), working in Martinique, has suggested the use of a pruning paste consisting of 2, 4-D, fuel oil and grease.

Since 1956 this Department has been conducting trials with a method of pruning bananas with the sodium salt of 2, 4-D. The method found successful has been to treat unwanted suckers with about 5 cm^3 of a 2 per cent solution applied from a plastic wash-bottle into the small cavity formed by the base of a petiole, or into the centre of the rolled-up spear.

Only suckers which are sufficiently developed can be treated, since it seems essential that the solution should be held by part of the plant.

Where the solution has been correctly applied, no damage has been observed on the parent stem or on untreated suckers on 600 mats treated regularly every three months from March 1956 to October 1958. In a replicated experiment over the 30 months in question, plots pruned with 2, 4-D gave 655 stems with a total of 5218 hands per acre, compared to plots pruned normally which gave 637 stems with 5165 hands per acre. (Difference for significance at 5 per cent level 71 stems and 575 hands.) There was an indication that where bananas were not earthed-up, wind damage was reduced (384 stems lost per acre as opposed to 547), but earthing-up reduced damage to 212 stems per acre and there was no further reduction from chemical pruning.

ACKNOWLEDGEMENT

The writer wishes to express his thanks to Pamol Ltd, for permission to publish this note.

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Chocolate Flavour: Its Assessment and Speculation as to Its Probable Origin

An Attempt to Reconcile Practical Knowledge of the Flavour of the Main Varieties of Cocoa with Recent Scientific Advances

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Although it is interesting to speculate by what sequences it was discovered more than 400 years ago that cocoa beans had not only to be fermented, but also roasted, before the desired flavour was obtained, it was not until the beginning of this century that scientists began to investigate the underlying scientific principles. In 1937 Knapp made a most comprehensive survey of the knowledge then available. Knapp brought to bear many years of practical experience in chocolate factories and on plantations, and directed his researches principally to the changes brought about during the fermentation of the bean. On pages 127–130 of his book detailed consideration is given to the nature and formation of cocoa aroma. The conclusion he reached, on page 130 that ' the production of the substances which, on roasting, give the characteristic odour and flavour, remains obscure ', is still true, but much more is now known of the changes involving glycones, aglycones, polyphenols and the proteins.

FLAVOUR REQUIREMENTS OF MANUFACTURERS. REVIEW OF DESCRIPTIVE AND STATISTICAL METHODS OF ASSESSING FLAVOUR

The ultimate requirement of the manufacturers, and the aim of the producers, is to obtain the most desirable chocolate flavours of the various types required. It is at this point where the difficulties are met in coordinating the requirements of industry with the guidance requested by scientists and plant breeders regarding chocolate flavour. So far, tasting in some form or other is the only guide to progress. But tasting is a highly subjective matter, which is difficult if not impossible to express numerically in the objective manner desired by scientists. As pointed out by Forsyth and Rombouts (1951a) the difficulties are considerable and must remain a serious obstacle to progress. Commercially, cocoas are judged on the characteristics of the chocolate made from them. This introduces a further source of variation, but considerable progress has been made in standardizing the procedure for the making of small scale samples. This involves roasting in a thermostatically controlled electric oven with fan circulation and

subsequent treatment in specified machines (C.S.A.C.) for specified times. The method is still in the development stages, but it has shown that similar beans treated in different laboratories can give similar chocolates.

It is also possible for experienced tasters to assess unsweetened paste or roughly ground nib made from roasted beans. This method can, with experienced tasters, enable a rapid and fairly reliable selection to be made of the better samples and thus save much time and material.

Various organizations have investigated the application of numerical methods to the tasting of chocolate. During 1950 the Cocoa Scientific Advisory Committee (C.S.A.C.) of the Cocoa Chocolate and Confectionery Alliance had considered numerical systems of scoring. The first attempts to apply statistical methods were described in a paper read by MacLean and Wickens at the 1951 Cocoa Conference and attempts were made to use this by the C.S.A.C. Although the method appeared suited to the local panel at the West African Cocoa Research Institute (W.A.C.R.I.), the industry considered, at that time, that it would prefer to rely on the descriptive opinion of its experienced tasters and this led, in the case of West African experimental cocoas, to the C.S.A.C. reporting the broad conclusion that a cocoa was either within or without the West African Amelonado range. A very comprehensive account of a numerical system was made by de Witt (1954) at the Imperial College of Tropical Agriculture and also by Wickens (1953, 1955) at the W.A.C.R.I. It may well be that eventually these systems will be of great value, but at the moment it is difficult to reconcile the scoring developed by these methods with the overall opinion of men who have a lifetime experience of chocolate.

The industry in the U.S.A. uses a simple form of scoring (Bowman, 1957) but they also describe samples as resembling certain established types familiar to them, e.g. Rio-Caribe, Bahia, Caracas, etc.

In the industry, chocolate tasting is generally carried out by experienced tasters. In common with tea tasters, coffee tasters and wine tasters, these men have developed highly trained palates and know when a thing is good. To describe their reaction is another matter and many strange terms are used. In tasting chocolates the effects on the taster may be classified as follows:

(*1*) Acidity
(*2*) Chocolate aroma
(*3*) Subsidiary flavours
(*4*) Bitterness and/or astringency.

This is the order in which they normally manifest themselves to the palate, although effects such as bitterness are often present throughout. With acidity (Powell, 1958) may go some of the subsidiary flavours, but not all. *Table 1* presents some of the terms used by tasters to describe subsidiary flavours with suggestions as to the probable origin. Nine of these flavours are mentioned by de Witt and are probably characteristic of the cocoa with which he worked (Trinitario and a little Criollo).

Many of the flavours mentioned in *Table 1* are associated with 'fine' cocoas. These only constitute about 80 000 tons in a world crop of 800 000 tons—say 5 to 10 per cent (*Colonial No. 192*. Wadsworth, 1955). While the commercial importance of Amelonado cocoa is appreciated (Wadsworth

Table 1. Subsidiary flavours found in cocoa and/or chocolate

	Flavour description	*Probable cause*
Due to natural causes	Acid	Natural.
	Floral	Natural. Due to type of bean (Arriba).
	Nutty	Due to type of bean (Criollo).
	Woody	Lack of chocolate flavour.
	Fruit, Honey, Liquorice, Plum pudding, Raisin, Winey	Natural and probably due to nature of pulp and type of bean (Trinitario).
Due to fermentation	Beery, Yeasty, Bready	The fermentation has probably stopped at some point where yeasts predominate. Imperfect mixing may have an effect.
	Caramel toffee, Butter	Fermentation.
	Whitewash, Fish, Ammonia, Gamey	Over-fermentation and protein breakdown.
	Coconuts	May be over-fermentation.
	Beetle, Metallic	Due to under-fermentation and probably descriptions of astringency.
	Bitter, Astringent	Due to under-fermentation.
	Walnut skins	Probably astringency plus mould.
Due to drying and storing	Ham, Smoke, Kipper	Drying and storage.
	Mouldy, Earthy	Drying and storage.
	Dirty	Probably contamination in drying.
	Reasty, Tallowy, Burning tapers	Unknown, but might be storage.
Due to contamination	Spice—usually cinnamon or cloves, Vanilla	Contamination.
	Coconuts	May be contamination.
	Disinfectants, etc.	Adventitious introductions or contamination.
Due to processing	High over-roast	Processing.
	Burnt sugar	Processing, but may be drying and fermentation in certain Samoan and New Guinea types.

1955), some knowledge of the finer cocoas is necessary for the future guidance of plant breeders and research workers. It might, therefore, be helpful to give a broad classification of the groups into which cocoas fall on a flavour basis. These groups are:

(*1*) Within the West African range
(*2*) Criollo
(*3*) Criollo–Forastero (Trinitario)
(*4*) Ecuador
(*5*) Incompletely fermented cocoa
(*6*) Unfermented.

In considering in more detail the flavour characters of cocoas in each of the above classes, it is assumed that cocoas showing obvious post-harvest defects such as smoky taints or mould are excluded.

Cocoas falling within the West African range

The main flavour requirement of these cocoas is an adequate chocolate flavour unaccompanied by undue bitterness or astringency, or by too marked subsidiary flavours. This is what is meant by ' mild '. It can be slightly acid. A bad West African is often bitter, astringent, showing little chocolate flavour and considerable off-flavours.

Amelonado cocoas from other areas, if well prepared, may fall within this range, but they are frequently under-fermented, containing many fully purple and slaty beans, and have to be considered in class 5.

Criollo cocoas

These are essentially white seeded cocoas and therefore contain leuco-anthocyanins but no anthocyanins. In commerce it is rare to find parcels of cocoa prepared from beans which were entirely white. Perhaps certain Java cocoas are the most free from purple beans, but that is not to say such cocoas have the best flavour.

The chocolate flavour of Criollo is weak and delicate and is accompanied by a ' nutty ' or ' biscuit ' flavour. It should not be bitter. Growths from different plantations show differences, rather in the way wines may differ from château to château.

The best chocolate flavour is to be found in the Venezuelan Criollo cocoas, but this depends to a marked extent on the fermentation and drying and a mark which is good one year may not be so another year. Also the Venezuelan is not completely white—some pale blue seeds are permitted.

The other main areas of Criollo production are in Ceylon, Java and Samoa. In all these areas the cocoa is washed after fermentation. In Ceylon Criollo plantations have had poorer types introduced, which gives rise to difficulties in fermentation. A good Ceylon shows all the Criollo flavour characteristics but is often spoiled by slate. (When slate is roasted a flavour reminiscent of putrefied cabbage accompanies the bitterness and astringency.)

Java cocoa is frequently incompletely fermented. The cut beans have white patches which are bitter and astringent. The chocolate flavour is not very strong.

Much Samoan cocoa is dried too quickly in artificial dryers and some is contaminated by smoke. When dried too rapidly the cocoa tends to lack chocolate flavour and to show a ' staleness '.

All these cocoas require only a 2 to 4 day period in the sweat box. The subsequent drying is all-important and if too rapidly conducted leads to a complete loss of the desirable chocolate flavour.

Criollo–Forastero (Trinitario)

These are essentially cocoas of the Caribbean—Trinidad, Tobago, Grenada, St Lucia and areas of Venezuela round Rio Chico and Tucapita. Dominican cocoa although of Caribbean origin is more readily classified as incompletely fermented.

All these cocoas show strong chocolate flavours accompanied by marked subsidiary flavours likened to liquorice, plum pudding, raisin, etc., and with considerable bitterness. They require prolonged sweat-box periods of 7 days and in Grenada 11 days is normal. The produce of different countries and even different estates in the same country show marked but characteristic differences, mainly in the subsidiary flavours. The main flavour characteristics may be due to type, for similar trees grown in the Cameroons still show the Trinidad flavour; also the cocoas from some plantations in New Guinea show Trinidad flavours.

Ecuador cocoas

These cocoas have been separated from the Trinitario class because they show a distinctive floral bouquet. This seems to show occasionally in some breeders' samples of which the clones SCA 6 and SCA 12 are parents. The cocoa from Nacional trees is not fermented in the true sense. After removal from the pod it is spread out on mats to dry, and heaped at night, when a mild fermentation commences. In consequence of this mode of preparation there is much slate in Ecuador cocoa. It seems necessary to tolerate a certain amount of slate in order to develop the floral bouquet. The best cocoa is known as Selected Summer Arriba and this has a strong chocolate flavour with the distinctive floral bouquet described by some as roses and by others as Coriander.

Incompletely fermented cocoas

In some areas in Latin America, either through peculiarities of transport or through a desire not to lose too much weight, some Amelonado cocoas are incompletely fermented—or fermented to a point where the beans were killed and thus gave no undue amount of slate, but a high proportion of fully purple beans. As is to be expected, such cocoas, while showing some chocolate flavour are very bitter and astringent.

Unfermented cocoas

These are Venezuelan cocoas of the Irapa peninsula. The cocoas in this area are merely exposed to the sun and dried. There are many purple beans and much slate. Chocolate made from these beans is very bitter and slaty, but in the background there are signs of good potential quality.

PLANT BREEDING MATERIAL

The variety of cocoa types which are now being produced gives considerable scope to plant breeders in the production of new material. Work has been proceeding for many years in various centres. In due course these types will have to be assessed for flavour. A brief review of the existing collections of plant breeding material follows.

The first selection of trees for carefully specified characteristics was made at the Imperial College of Tropical Agriculture, Trinidad, during the years 1931–35 (Cheesman, 1934; Pound, 1931, 1932, 1933; Pyke, 1935). Working under Cheesman, Pound undertook the survey and selection from the local population which was to lead to the well known Imperial College Selections (I.C.S.). Concurrently Pyke and Cheesman established the

principles of successful vegetative propagation. Pound later led two expeditions up the Amazon and returned with new types of cocoa. Some of these were resistant to, or at least tolerant to, Witches' Broom disease. Others were later to prove vigorous parents in hybrid crosses. In 1952 a joint Anglo-Colombian expedition (Cope, 1953), with the I.C.T.A. team led by Baker, searched for cacao species in the upper reaches of the tributaries of the Amazon and Orinoco, mostly in Colombia.

Ghana, or the Gold Coast as it then was, has taken full advantage of new breeding material; as early as 1904–5 Trinidad trees from River Estate had been established at Aburi (Posnette, 1942) and may have had some slight effect over the years on the general quality of West African cocoa. During 1943–45 the W.A.C.R.I. took from the I.C.T.A. 115 new introductions (*Rep. W. Afr. Cocoa Res. Inst. 1944–45*, and *1947–48*).

These have formed the basis for many new and vigorous types now existing in Ghana. A comprehensive account of the flavour of some of these new varieties was given by Wadsworth in 1953. Ten of the varieties there mentioned have been released for general use (Rogers, 1955).

Collections of breeding material are also being made at Turrialba (Inter-American Cacao Center, 1958); these include 25 of the I.C.S. clones and many others from Costa Rica, Amazonia, Brazil, Guatemala, Indonesia and Mexico. There is also a modest collection in Malaya (*Malay. agric. J.* Oct 1950).

NEED FOR SMALL SCALE METHOD OF PREPARATION

With regard to small scale assessment, it was becoming apparent in 1945 that more consistent methods were required for the fermentation of small samples—perhaps as small as the seeds from a single pod, and in 1947 the C.S.A.C. outlined a method (*Report of the Cocoa Conference 1947*). This was followed up by MacLean (1950) and later by de Witt (1951, 1952). These were methods founded on micro-fermentation. Later Wadsworth and Howat (1954) devised an aseptic method based on specified temperatures and times. Forsyth and Rombouts had already made far-reaching fundamental discoveries on the sequence of changes taking place on fermenting cocoa. Following these principles Quesnel (1957) evolved a truly aseptic small scale method and this may have the greatest eventual promise in demonstrating the inherent chocolate flavour of cocoa beans uninfluenced by the microflora growing in the pulp. An excellent résumé of all this work is given by Quesnel (1957).

The two small scale systems (those of Wadsworth and Howat, and of Quesnel) of curing small quantities of cocoa were discussed at the Restricted Scientific Session (*Report of the Cocoa Conference 1957*, pp 145–175). Although no official comparison was made of the two methods, various members of the C.S.A.C. tried out the methods. At first the Wadsworth–Howat method gave more acceptable results when applied in this country to pods brought over by air. Latterly, Quesnel has demonstrated that his method can produce consistent samples. It would be fair to say that both methods have given useful results. Because they are based on quite different principles, they will be considered in more detail in relation to Rohan's practical investigations.

FIELD INVESTIGATIONS ON THE FULL SCALE

At the 1957 Cocoa Conference, ROHAN described some of the results following a comprehensive investigation into fermentation methods in Ghana (1957a, b; 1958a, b). The research comprised a careful operational enquiry into conditions prevailing in fermenting heaps combined with thorough chemical investigations and flavour assessments. The outstanding discovery was that in the outer layers of a fermenting heap, death of the bean can occur in 20 hours and 6 hours later the bean could be dried to give what was claimed to be an acceptable chocolate flavour—a total fermentation time of 26 hours. A new method of fermentation based on this discovery is now being tried in Ghana (ALLISON and ROHAN, 1958). Several other interesting observations were made; these included the statement that if the anthocyanin content of the beans fell below 10 per cent of the initial concentration an acceptable chocolate could be made. Much of the fall in anthocyanin concentration occurred during the drying period, provided the beans were dead when passed to the drying trays. Chromatographic analysis showed that the same polyphenols occur in West African Amelonado as in Trinitario, viz. two anthocyanins (3-L-arabino-glycoside and 3-D-galactoglycoside), four catechins (*epi*-catechin, catechin, *gallo*-catechin and *epi-gallo*-catechin), and three leucocyanidins.

Concurrently with Rohan, a team consisting of POWELL, WOOD and HOWAT (1957) and HOWAT (1957) made a similar investigation, but were not concerned so much with the underlying chemistry as to extend the principles enunciated in the small scale method of WADSWORTH and HOWAT (1954) to larger scale experiments. To this end they used vessels which could be ventilated and heated by warm water to obtain the necessary temperature for the prescribed times. Box fermentations were also performed. While the results were more consistent than with traditional Ghana methods, difficulties were experienced in keeping these larger quantities aseptic and perhaps for this reason the two specified temperature levels were not maintained as precisely as had been possible on the small scale.

A paper of very high quality was submitted by BRIDGLAND and FRIEND (1957). This dealt with field observations and experiments on New Guinea cocoa, which is a hybrid in the Trinitario group. The readings taken were similar to those of other workers: temperatures at the top, middle and bottom of heaps, pH values of the beans and also titrations of the extractable acids. Notes were made on times of death of the beans and other factors such as colour, odours at different stages and cut tests. The cocoas were finally assessed for flavour in the Antipodes by Messrs Cadbury–Fry–Pascall. It is interesting to note that fruity, raisin, liquorice and caramel flavours were frequently reported. The most interesting feature of this paper is that it affords comparison of the standard methods of fermentation in New Guinea (old technique) with a carefully planned and executed scheme to allow the principles of Wadsworth and Howat's small scale discoveries to be applied at the commercial level (new technique). Bridgland and Friend were successful in restraining the early rise of temperature and were able to keep the beans at 30° for at least 30 to 45 hours. Thereafter the temperature rose very rapidly to 50° and frequently to over 60° (HANCOCK, 1949). The general opinion (*Report of the Cocoa Conference 1957*, p 186) on samples of chocolate

prepared from beans from these new technique fermentations was that a proportion had slightly earthy or foetid flavours although some developed good chocolate flavour without side flavours of fruit, etc. The fear of producing earthy or foetid flavours prevented the commercial adoption of this system. It would appear that in this case the application of the small scale principle to commercial practice has revealed effects which seem to require further explanation.

EDEN (1958) describes the latest application of the techniques of 'broken fermentations'. It would appear that some progress has been made in securing less variable results, but it is not certain whether the uniformity of product is any greater than that obtained from equally carefully conducted fermentations by the 'old technique'.

When consideration is given later to the precursors of chocolate flavour, some attention will be given to the mode of death of the bean. It may be noted that in recent full scale experiments at the W.A.C.R.I. beans were killed by keeping them in a deep freeze and were subsequently fermented. The flavour of chocolate from these beans was found to be quite normal.

SPECULATIONS BASED ON THE CHEMISTRY UNDERLYING FERMENTATION AND THE FORMATION OF COCOA AROMA

Before passing to consideration of the substances which give rise to cocoa aroma, reference will be made to two recent publications (SWAIN, 1954a, b; *Report of the Cocoa Conference 1957*). At the 1957 Cocoa Conference were gathered nearly all the experts of the world on cocoa fermentations. An account of a restricted scientific session is contained in the Conference *Report* and those interested are referred to the sections between pages 145 and 200. The page references which follow are from this *Report*. Other references are given in the usual way.

Forsyth on pages 145–147 gave a résumé of the position at that time and made suggestions as to the line of future research. The main points of the survey were the enzyme nature of the changes occurring within the bean immediately following its death, that this was the stage where chocolate precursors were formed, and he proposed the use of gas–liquid chromatography to elucidate the nature of cocoa aroma.

ATTEMPTS TO RECONCILE FORSYTH'S HYPOTHESIS WITH ROHAN'S RESULTS

There was considerable discussion (pp 148–149) on the conditions necessary for what Forsyth called the anaerobic hydrolytic phase during which the chocolate flavour precursors are formed and which lasts normally 48 to 72 hours. Efforts were made (p 209) to reconcile Forsyth's hypothesis with Rohan's rapid method (6 hours) of curing (p 203).

In order to satisfy Rohan's claim (p 149) to obtain cocoa aroma in as little as 6 to 12 hours after death it is necessary to show that the glycosidase can complete its action within six hours. The conditions for the glycosidase to act are: (*i*) death of the beans, (*ii*) an optimum temperature of 45° C and an optimum pH of 4·5. Although a pH lower than 4·5 restricts activity, a pH above 4·5 does not have such a marked effect (Quesnel, p 151). Air and catechins restrict the activity. FORSYTH (1957) and QUESNEL (1958) have shown that within 4 hours 80 per cent of the pigment had been hydrolysed

under optimum conditions for the glycosidase. KNAPP has shown that at 45° the bean dies within 2 hours (1937a). The feature of Rohan's method is the rapid rise in temperature within the first 24 hours. It is therefore conceivable that the death of the bean in Rohan's experiments is by heat alone and not by a combination of heat and acid as postulated by Forsyth. The crux of the problem would seem to be in the inhibition exerted on the enzyme by the oxygen. The oxygen has to diffuse through the testa. Further, owing to the greater microbial activity in Rohan's experiments, the concentration of oxygen may not have been unduly high, and the conditions might have been such that a considerable proportion of anthocyanin would have been hydrolysed. Although some chocolate flavour is produced by Rohan's rapid method, there does seem to be a larger proportion of purple beans (ALLISON and ROHAN, 1958). This would be in accordance with enzyme activity which had been restricted by oxygen or by too short a time. On the whole it would seem that Forsyth's hypothesis that it is during the glycosidase hydrolysis that the aroma precursors are produced is supported by Rohan's work. Perhaps some confirmation might be obtained by crushing beans in an inert atmosphere and then allowing the glycosidase to act anaerobically under optimum conditions of temperature and pH.

THE NEED FOR EMPIRICAL RESEARCH ON REACTIONS BETWEEN THEOBROMINE AND LEUCOANTHOCYANINS IN PRODUCING PRECURSORS OF COCOA AROMA

It was KNAPP (1937b) who first discovered that a methanol extract of fermented beans gave a cocoa aroma when heated. FORSYTH and ROMBOUTS (1951b) carried this further and found that it was the complex leucoanthocyanin fraction from fermented beans which, when roasted with theobromine, gave the aroma. It did not, however, give an aroma with caffeine.

Those who have performed these experiments might not agree that a true chocolate aroma is produced. Nevertheless the aroma is sufficiently reminiscent of chocolate to warrant further investigation. It would seem that in its earlier stages such a research would have to be empirical rather than logical, and could take the form of post-graduate research at some school of chemistry in the U.K. The reason why caffeine does not show this reaction should be one of the objectives, for the understanding of this reaction might point the way to further progress. With regard to the nature of the leucoanthocyanins giving this reaction, it could be shown first whether or not the substance synthesized by SWAIN (1954b) and having the constitution of a simple leucoanthocyanin, gives an aroma when heated with theobromine. DE WITT (1956) gave a comprehensive account of the amino-acids derived from the hydrolysis of cacao proteins. Some of these, e.g. histioline, proline and tryptophane have —N—CH— linkages similar to those of the xanthine bases. Empirical investigations with these substances and polyphenolic C_{15} structures might give some indications of the types of reactions taking place.

The need for temperatures of about 140° C to promote these reactions has always been regarded as a first necessity. However, Brown on p 165–170 suggested that the roasting process, while altering other components (e.g. causing condensation of bitter substances to less bitter complexes) need not

necessarily develop chocolate aroma. This aroma might have been present all the time but obscured by other more powerful substances. Some practical experience supports this view. Chocolate can be made from beans roasted at temperatures as low as 105° C. Such chocolate is more acid, more bitter and more astringent than usual, but the aroma is present. The manufacture of such chocolate also presents some technical problems associated with the physical character of low roasted beans. It is possible that both effects are happening together. It is usually accepted that the aroma is concentrated in the cocoa butter. This may be erroneous. Practical experience indicates that when cocoa mass is pressed, the odour of the cakes, from which over two thirds of the cocoa butter has been removed, is quite as strong if not stronger than that of the expressed butter.

It will be apparent that at this juncture the available observational data are in conflict, and a first task will be to resolve these differences by all available methods including gas–liquid chromatography.

USE OF GAS–LIQUID CHROMATOGRAPHY

As previously mentioned, it was Forsyth (p 147) who suggested the application of gas–liquid chromatography to the further elucidation of these problems.

Since that date (September 1957) research in this field of cocoa aroma has been commenced both in Germany and in the U.K., and no doubt work will be published in the near future.

In the meantime it may be useful to indicate the possible application of this new technique, based not so much on theoretical considerations as on the results of the operational researches already reported, and on the factory experience with commercial cocoas.

If it should prove that cocoa aroma can be associated with characteristic peaks in a pictogram, a wide field of research lies ahead.

In the first instance it might prove profitable to compare the pictograms of mass made from unroasted beans with those made from beans roasted at 105°, 120° and 150° C. The peak of the theobromine–leucoanthocyanin reaction could be studied.

The peaks associated with the various stages in a fermentation could be determined, and the times at which the precursors appear could be defined. An opportunity would then be afforded to concentrate on this stage. Perhaps ROHAN's rapid tray technique (1958a, b) could provide material both for the gas-liquid technique and for conventional column chromatography on a comparatively large scale.

MATERIAL

From the practical point of view it would be preferable to use fairly standard materials and also to avoid Criollo cocoas. Although Criollos have no anthocyanins and much leucoanthocyanin, the chocolate flavour is much more difficult to develop and is probably not so well marked as with tinted beans. In West Africa probably ordinary Amelonado would be suitable, although it is not as standard as some would believe. In the West Indies perhaps I.C.S.95 would be the best type.

COOPERATION WITH OTHER INDUSTRIES

Some of the techniques mentioned have already been used by the tea and coffee industries. There seems to be much common ground between tea, coffee and cocoa. Although the plea of Lamb (p 172) for some form of cooperation between these industries seems to have passed unheeded, it could not be other than to the mutual advantage of all three interests if an effort were made to establish some form of liaison.

WORLD SITUATION IN SUPPLY AND DEMAND

With world production and world consumption in delicate balance at approximately 820 000 tons there is the distinct probability that even in the face of relatively high price levels, consumption in the near future may outstrip production. The reason underlying this is that the ' iron curtain ' countries are now at the point where industrial expansion can proceed in geometrical progression. In contrast, new plantings, however massively undertaken, take three to five years to come into fruit. An expansion of 100 000 tons in production within three years is scarcely possible. On the other hand, the world used 897 000 tons in 1957. In these circumstances improvements in yield by the planting of new varieties and the increasing use of chemicals to control pests, both in the field and in the store, will become common practice and will put mounting pressure on the organization and methods of flavour assessment.

THE POTENTIAL IMPORTANCE OF CHOCOLATE FLAVOUR

It will be apparent from the foregoing paragraph that there is a distinct possibility of world demand exceeding supply in the near future. In periods of previous shortage much study was given to fats which were alternative to cocoa butter, and the problem of making satisfactory alternative fats has been solved technically. The problem of cocoa flavour is not yet solved, but it is not inconceivable that once the essential structure is discovered it may be possible to synthesize it—rather in the way vanillin is made today. If this should come about the implications are far-reaching. To make 100 tons of milk chocolate requires about 73 tons of beans, of which about 11 tons go to make the colour. The remaining 62 tons is used to make cocoa butter. Thus six sevenths of the beans are used to make cocoa butter. Suppose the world consumption of milk chocolate is 75 per cent of the whole, then from a world crop of 800 000 tons, 600 000 tons will go to make milk chocolate. If the cocoa butter were replaced completely by alternative fats (as can now be done) then six sevenths of 600 000=514 000 tons of beans would be released. The extreme case has been taken here, but if the current delicate supply situation persists, there is no doubt that the tendency will be towards the use of alternative fats plus cocoa flavour.

CONCLUSION

Knowledge is power. The more that can be known about cocoa, in all its aspects, the more closely will it be possible to integrate the commercial, the research and the productive sides of the industry to the mutual advantage of all.

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Some Notes on the Conformation of West African Dwarf Cattle

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Some controversy exists regarding the origin of the dwarf cattle of the Guinea coast of Africa. These cattle are variously described as *Muturu* (Hausa for ' small '); Lagoon cattle (*Race des Lagunes*); Forest, Pagan, Kirdi, Somba cattle; Nigerian Dwarf Shorthorn; Dwarf Agbosome; (Doutressoulle, 1947; Mason, 1951; Faulkner and Brown, 1953; Faulkner and Epstein, 1957).

With Adametz, some authorities consider these dwarf cattle to be degenerates of a larger type, viz. *Bos namadicus falconeri* (Faulkner and Epstein, 1957). Others (Doutressoulle, 1947; Jeffreys, 1956) consider them to be descendants of a small-sized ancestor, *Bos brachyceros*.

Curson and Thornton (1936) classify these cattle as *Bos brachyceros*, but also state: ' Through living in such an unfavourable environment, Brachyceros cattle have in the course of centuries (or rather millennia) deteriorated and are now considerably smaller than their relatives in Europe, e.g. Jersey, Guernsey and Kerry '. According to Wright (1955), dwarf animals may show better adaptation to a hot, humid environment, on account of their proportionately larger skin surface.

Jeffreys (1956) considers the West African dwarf cattle to breed true to type, in so far as size and particularly height are concerned. Even as a distinct type, however, these cattle may present a stunted conformation and/or possess less desirable physiological features.

The same author, referring to Gates's (1946) explanation of dwarfism, states (1951) that the West African dwarf cattle are ateleiotic (i.e. true miniatures of a larger type), rather than achondroplastic (i.e. showing abnormal proportions). According to Gates, ' ateleiotic dwarfism is the result of growth practically ceasing at an early age in childhood '. This suggests that dwarf cattle must have a very juvenile appearance, since growth rate in the early stages of their life is already low. Growth, however, does not cease at an early stage with these dwarf cattle, but starts at a low level and continues at a decreasing rate for a long period of time. Thus a considerable proportion of their development takes place in the later stages of life, when their growth rate is very low. (These cattle attain approximately 40 per cent of their mature weight at two years of age.) The resulting animal shows little development in the late-maturing parts of the body; in other words it is a juvenile type, but not necessarily a dwarf type. It seems likely, therefore, that Gates's explanation of ateleiotic dwarfism is not applicable to these dwarf cattle.

The Nigerian Livestock Mission reports with regard to the *Muturu* type of dwarf cattle: . . . ' from the point of view of meat-carrying capacity, (they)

have an exceptionally good body conformation' (SHAW and COLVILLE, 1950). Likewise, FAULKNER and EPSTEIN (1957) state: 'Although small, the Dwarf Shorthorn possesses a compact body of exceptionally good beef conformation'.

In order to obtain a more precise picture of the conformation of West African dwarf cattle, a sample of animals was measured and weighed and the results compared with data available for some other types of cattle.

MATERIAL AND METHODS

The sample was taken from two herds of dwarf cattle near Abor, in the southeastern part of Ghana. Climatic conditions in the area may be summarized as follows. Mean annual rainfall: 90 cm, 60 per cent of which falls in the period March to June. Mean monthly temperature (1500 hours) ranges from 27°C in June to 31°C in March. Relative humidity (0900 hours) 67 to 81 per cent; slightly less at 1500 hours. A large part of the area is swampy and liable to be flooded in the rainy season. Vegetation consists mainly of grasses with patches of dense thicket and coconut trees. Because of the high phreatic level the effects of the dry season are less severe than in the savannah proper.

As most of the local herds consist of only a small number of animals, it was not possible to obtain a sufficiently large number of bulls or bullocks. The sample was therefore entirely made up of empty or newly pregnant cows with at least six permanent incisors.

Body measurements included: (*1*) Body length (anterior edge of shoulder to posterior point of pinbone); (*2*) Height at withers; (*3*) Height at hips; (*4*) Depth of chest; (*5*) Width of chest (*4* and *5* just behind shoulder); (*6*) Width of hips; (*7*) Width at pinbones; (*8*) Length of rump (anterior edge of hipbone to posterior point of pinbone); (*9*) Length of tail (ventral); (*10*) Length of head (poll to muzzle, including the latter); (*11*) Width between eyes (at inner eye corner); (*12*) Chest girth (just behind shoulder). In addition to the above measurements body weight was recorded.

Measurements were taken by means of gauges, except chest girth and length of tail, which were measured by tape. Body weight was recorded by suspending the animal in a sling from a 5 cwt spring balance. This method was chosen on account of the comparatively low weight of the cattle and because the apparatus was easily transported by manpower. Animals were weighed and measured early in the morning before access to food or water was available.

RESULTS AND DISCUSSION

In *Table 1* the mean value and the coefficient of variation for the different measurements are given. It is obvious from these data that West African dwarf cattle are very small. Most of the modern breeds of domestic cattle are about 50 per cent higher at the withers and their body length is frequently 40 per cent greater. The most striking difference lies in the low body weight of these dwarf cattle. This low body weight is not a reflection of heavy lactation strain, since the milk yield of these cattle is of the order of 50 gallons per lactation period. The condition of the cattle under observation was not below average.

Table 1. Mean value and coefficient of variation for twelve body measurements (cm) and body weight (kg) for 40 mature West African dwarf cows

Measurement	*Mean value*	*Coefficient of variation* (%)
1. *Body length*	107·3	3·8
2. *Height at withers*	87·7	2·9
3. *Height at hips*	91·0	3·1
4. *Depth of chest*	51·6	3·7
5. *Width of chest*	27·7	4·9
6. *Width of hips*	35·4	4·8
7. *Width at pinbones*	14·4	9·3
8. *Length of rump*	36·2	4·1
9. *Length of tail*	57·4	3·9
10. *Length of head*	40·3	3·0
11. *Width between eyes*	15·9	9·2
12. *Chest girth*	130·4	4·3
13. *Body weight*	166	8·7

Table 2. Body measurements and body weight of various types of cattle, expressed as percentage of height at withers

Measurement	*A*	*B*	*C*	*D*	*E*	*F*	*G*
Height at withers	100	100	100	100	100	100	100
Body length	122·3	111·1	115·4	119·1	115·2	119·0	?
Depth of chest	58·8	51·1	53·1	56·8	52·7	55·7	55·2
Width of chest	31·6	30·1	33·1	—	—	—	37·8
Height of chest	29·8*	48·0	46·9*	43·4	47·3	44·3	44·8*
Width of hips	40·4	34·5	39·5	—	—	—	—
Length of rump	41·3	37·4	39·0	—	—	—	—
Chest girth	148·7	140·8	140·8	—	—	—	141·7
Body weight	188	330	326*	394	172	295	167

A. Dwarf cattle (present data).
B. Milking Shorthorn (Dawson *et al.*, 1955).
C. Friesian (Bekedam, 1958).
D. Aberdeen-Angus and Hereford, mature cows.
E. Aberdeen-Angus and Hereford, heifer calves, six month.
F. Ibid., 12 month. (D,E,F: Brown *et al.*, 1956).
G. *Muturu* (Joshi *et al.*, 1957).
* Estimated.

It is interesting to compare the observed data with those of other types of cattle on a per unit basis. Expressing the data in *Table 1* as percentages of wither height, *Table 2* relates the results with similar values for some other types of cattle.

Although the data recorded in *Table 2* are incomplete, certain tendencies emerge. In the case of body weight it may be seen that West African dwarf cattle are comparable with the six-month old heifers in column E. As in both types of cattle body weight is less than 100 kg at birth, it follows that the growth rate is disproportionately higher in the heifer calves of column E. This difference is due to a higher rate of body weight increase in the heifer calves, rather than to a higher rate of skeletal development in the dwarf cattle. The difference in relative body weight between the two groups increases with age. At maturity this value for the beef type in column D is more than twice that of the dwarf cattle. It is not unlikely that environmental influences are responsible for part of this difference, since the condition of the beef cattle in column D, kept on American experimental stations, may have been better than that of the dwarf cattle, kept under African levels of management and nutrition.

Using the formula: ($\pi r^2 \times$ body length $\times$ sp. gr.), the calculated body weights are 145 and 327 kg for West African dwarf cattle and Milking

Shorthorns respectively. In the former this value is 12·5 per cent less than the actual body weight, in the latter the difference amounts to approximately 20 per cent. This suggests that with the West African dwarf cattle the excluded parts of the body make only a modest contribution to total body weight.

Further consideration of body measurements, as shown in *Table 2*, indicates that these dwarf cattle are low-set, in an absolute as well as in a relative sense. This is in accordance with the report by JOSHI *et al.* (1957). These authors further state that West African dwarf cattle, though low-set, lack depth of chest. Present data indicate, however, that these cattle are deep-chested and short-legged, relative to their wither height.

On the basis of the available evidence it is difficult to decide whether West African dwarf cattle are purely ateleiotic or purely achondroplastic. In a strict sense they are not true miniatures of a larger type of cattle, being relatively longer and considerably shorter legged. Apart from their relatively long body they resemble the small Dexter cattle of Ireland, which display achondroplasia.

Even when considering the short legs of these cattle as an anomaly (and not as a clear indication of suitability for beef production), their relative proportions show that their conformation compares favourably with that of modern beef cattle. This conformation is particularly encouraging, if one takes the unfavourable environment and the lack of selection for beef characters into consideration.

Although it is strongly suggested (JEFFREYS, 1956), that improved environment fails to alter the size (absolute) of dwarf cattle, it is by no means certain whether under favourable conditions the relative proportions and in particular the body weight of these dwarf cattle would appear unalterable. Without this information it is impossible to assess the real potential and the economic usefulness of the West African dwarf cattle under improved levels of management and nutrition.

SUMMARY

Body measurements and body weights were recorded in a sample of West African dwarf cattle in the lagoon area of southeastern Ghana. Relative proportions are compared with those of some other types of cattle. It is concluded that West African dwarf cattle are probably achondroplastic rather than ateleiotic. The cattle are of pronounced beef conformation, though their short legs are possibly anomalous. More research is needed to determine the real potential and economic usefulness of these cattle under varying levels of management and nutrition.

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The Composition and Digestibility of Some Conserved Fodder Crops for Dry Season Feeding in Ghana

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PART III. FODDERS FOR IRRIGATION

The inclusion of irrigated fodders in a study of conserved fodder crops is due to the relationship in terms of the provision of fodder for dry season feeding.

A programme of small dam construction in the southern savannah of Ghana has recently been initiated by the Government. As this is predominantly cattle country the primary purpose of these dams is to supply drinking water during the dry season. Undoubtedly small scale irrigated cultivation will develop and irrigated fodder crops may follow. At the Nungua Agricultural Research Station on the Accra Plains, irrigated fodder crops, notably millet and maize, have proved a useful standby in the dry season especially when silage and hay stocks threatened to be insufficient. A great advantage is that a large bulk of material can be grown in a fairly short time should the need arise. In an experiment at Nungua, irrigated fodder millet yielded 10 tons of green material with upwards of a ton of dry matter per acre after only 39 days. By 8 weeks the yield of dry matter was 3 tons per acre. It should be pointed out, however, that such yields cannot be obtained without the application of nitrogenous and phosphatic fertilizers.

Fodder millet and maize were grown under irrigation for this study. Fodder millet and velvet bean mixture was also grown but was not actually irrigated due to early rains; the data are included since this is potentially a useful mixture for irrigation.

Bana grass, Guatemala grass, Guinea grass and Centrosema have also been grown successfully in a valley bottom below a small dam where they obtained water from seepage rather than actual irrigation. It is probable that all four would produce a considerable amount of keep without irrigation in mild dry seasons.

EXPERIMENTAL PROCEDURE

The experimental procedure and animals used were the same as in Parts I and II of this series except for Centrosema and Guinea grass where sheep were used for the digestion trials.

DESCRIPTION OF THE FODDERS USED

Bana grass (Babala millet × Napier grass). This grass is a sterile hybrid of a variety of *Pennisetum typhoideum*, known as Babala millet, and *Pennisetum purpureum* (Meredith, 1955).

Originating from a cross by Geldenhuys at Potchefstroom, South Africa, it was introduced to Ghana by the Crop Husbandry division of the Faculty of Agriculture in 1955 (NYENHUIS, 1959). So far it has only been grown on the Nungua Research Station where it has shown promise as a supplementary fodder with a minimum of irrigation. Unlike Napier grass (*P. purpureum*) it remains fairly soft and palatable well into maturity and therefore does not require the same careful management. For this trial the grass was cut during the dry season when between eight and ten feet tall. The appearance was rather dry and stemmy but bullocks and sheep ate all but the toughest stems readily.

Centrosema (*Centrosema pubescens*). A limited amount of Centrosema has been grown successfully at Nungua alongside irrigation channels and in areas where the soil does not dry out during the dry season, such as the seepage area below dams. A certain amount has also established itself on higher ground.

The composition data given in *Table 1* were obtained from Centrosema grown at Nungua but the data in *Tables 2* and *3* were obtained from Centrosema grown under the moister conditions of the forest.

Guatemala grass (*Tripsacum laxum*). This grass was cut between five and six feet tall; contrary to expectations cattle and sheep ate the material avidly despite its rather harsh appearance.

Guinea grass (*Panicum maximum*). This grass was collected during the dry season from a valley bottom where the soil remained moist enough to sustain lush growth. The grass was in flower when cut for feeding trials.

Maize (*Zea mays*). This crop was grown under similar conditions to the fodder millet, on the field scale for dry season feeding. When harvested the grains were between the milk and the dough stage.

Fodder millet (*Pennisetum typhoideum*). Nondescript seed from Accra Market was planted at the end of the rains in rows two feet apart on flat ridges with an irrigation channel between. Depending on weather conditions the crop was irrigated once or twice weekly. Cuts were taken at 39, 49, 56, 62 and 70 days. As the plots were not large enough to allow a digestion trial on the material harvested, a digestion trial was carried out on fodder millet grown on the field scale and harvested at a similar age and crude chemical composition as the fodder millet harvested at 8 weeks. The plants had eight nodes and were beginning to shoot ear.

Millet and velvet beans (*Stizolobium deeringianum*). This mixture was never actually irrigated as early rains made it unnecessary. The material was harvested at 7 and 10 weeks after planting when the millet was at the 7 and 10 node stage respectively, having shot ear in the second case.

In *Table 1* chemical composition data are presented for the green fodders examined. The usefulness of these data is limited by the fact that except for fodder millet and velvet bean mixtures, the composition was estimated and elaborated by digestion trial at only one period of growth in each case. The change in composition with period of growth is of greatest significance with annual crops such as fodder millet and a striking increase in crude fibre over a relatively short period of time can be seen in *Table 1*. It was not possible to conduct a digestion trial on the fodder millet at each stage and therefore no estimate of digestible nutrients or starch equivalent for each

Table 1

Feed	Stage or age	Crude nutrients %				
		Dry matter	Crude protein	N-free extract and fat	Crude fibre	Ash
Bana grass	Mature	30·2	1·4	16·6	9·5	2·7
Centrosema	Mature	27·0	4·9	11·4	8·0	2·7
Guatemala grass	Mature	31·2	2·9	16·6	9·2	2·6
Guinea grass	Early flowering	20·0	2·0	10·2	5·6	2·3
Maize	Milky–dough	24·5	2·4	10·8	6·4	2·1
Fodder millet	5 weeks 4 nodes	10·2	2·0	—	2·6	—
Fodder millet	7 weeks 8 nodes	15·8	1·4	—	5·6	—
Fodder millet	8 weeks 8–10 nodes	19·7	1·6	—	7·3	—
Fodder millet	9 weeks 8–10 nodes	22·8	1·7	—	8·0	—
Fodder millet	10 weeks 8–10 nodes	25·3	1·8	—	9·0	—
Fodder millet used for trial	8 weeks 8 nodes	16·0	2·2	7·2	4·8	1·8
Millet and velvet beans	8 weeks	19·4	1·6	9·2	6·7	1·9
Millet and velvet beans	10 weeks	22·8	1·3	11·6	8·0	1·9

Table 2

Feed	Stage or age	Digestion coefficients %					No. of animals
		Dry matter	Organic matter	Crude protein	N-free extract and fat	Crude fibre	
Bana grass	Mature	59·0	62·8	51·1	63·7	63·0	2
Centrosema	Mature	53·5	53·2	62·4	58·0	39·5	10 sheep
Guatemala grass	Mature	63·5	65·5	75·2	63·4	71·7	2
Guinea grass	Early flowering	61·0	63·2	65·1	61·2	66·6	6 sheep
Maize	Milky–dough	63·0	64·3	68·4	55·5	64·1	2
Fodder millet	8 weeks 8 nodes	71·8	76·9	79·5	77·1	74·5	3
Millet and velvet beans	8 weeks	64·8	64·8	68·5	64·9	73·8	6
Millet and velvet beans	10 weeks	60·8	60·8	53·3	63·6	66·2	5

Table 3

Feed	Stage of age	Digestible nutrients %			Starch equivalent	Nutritive ratio
		Crude protein	N-free extract and fat	Crude fibre		
Bana grass	Mature	0·7	10·4	6·0	14·4	20
Centrosema	Mature	3·1	6·6	3·2	11·5	4
Guatemala grass	Mature	2·2	10·5	6·6	16·7	8
Guinea grass	Early flowering	1·3	6·2	6·1	12·0	9
Green maize	Milky–dough	1·6	6·0	4·1	9·9	6
Fodder millet	8 weeks 8 nodes	1·7	5·6	3·6	9·6	6
Millet and velvet beans	8 weeks	1·1	6·0	4·9	10·1	9
Millet and velvet beans	10 weeks	0·7	7·4	5·3	11·2	16

stage can be offered but it is clear from the millet and velvet bean data in *Tables 2* and *3* that digestibility and starch equivalents can change equally rapidly.

Where regenerating fodders such as Bana grass, Guatemala grass and Guinea grass are grown and from which leafy herbage is cut repeatedly at a similar stage of growth this may be less important. Stage of growth and season have been shown to have only a small effect on the composition of Centrosema when grown under rain forest conditions of well distributed rainfall (OYENUGA, 1957; WILSON and LANSBURY, 1958) or irrigation.

From *Table 3* it can be seen that the nutritive ratios of these feeds are mostly closer than those of the hay and silage crops reported earlier in this series. With the exception of the mature Bana grass and the older millet and velvet beans, all are suitable for meeting the maintenance requirements of beef and dairy cattle or sheep. The Centrosema, maize and fodder millet have a close enough nutritive ratio to be suitable for meeting maintenance and production requirements of beef cattle or a moderate level of milk production.

The Bana grass tested was probably rather too mature and appears to need supplementing with a higher protein feed but this would not be so if the cuts were taken earlier.

The older millet and velvet bean mixture is low in digestible protein and the digestion coefficient for protein is considerably lower than for the younger mixture. The digestible protein content of both mixtures is surprisingly low. Even allowing for a low protein value in the millet this indicates that the contribution of protein from velvet beans when sown mixed with millet may not be as high as generally expected unless care is taken to ensure a high proportion of velvet bean foliage in the harvested crop. This is not easy to ensure as millet tends to grow vigorously in the early stages at the expense of the velvet beans which become shaded and stunted. Planting in alternate pairs of rows seems to be better than alternate rows.

CONCLUSION

Of the eight green fodders examined, the Centrosema, green maize and fodder millet were capable of providing adequate energy and protein for growth and milk production in cattle. The Guatemala grass, Guinea grass and 8-week millet and velvet bean mixture would need slight protein supplementation for optimum performance but might be adequate for conditions of extensive production. The mature Bana grass and the 10-week millet and velvet beans mixture are too low in protein and would need supplementation.

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Notes on the Composition of Cattle for Slaughter and the Availability of Meat in Uganda

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A knowledge of the nutritional status of any country can be gained by carrying out nutritional surveys and by collecting statistical data of production and availability of food for the population. Although these surveys yield the most accurate results, they require a considerable amount of time and highly trained staff and are therefore very expensive. Other methods used are mainly based on estimates of production and marketing or on surveys of small areas which are then applied to the whole country. From the data obtained by statistical means, the availability of food per head of population can be calculated and then, by deduction from the average chemical composition of commodities, the nutritional values are obtained.

In the case of meat, these factors may be very misleading as they are based on the analysis of carcasses in America and in West European countries where the standard of animal husbandry is usually disproportionately higher than in undeveloped countries.

Zebu type cattle in Uganda have been studied by an analysis of the carcasses; and the availability of meat has been calculated from data based on this analysis and on the numbers of hides sold which, in the Uganda Protectorate, are channelled through three centres at Masaka, Kampala and Mbale.

These regions cover the following administrative districts:

Region I — Masaka, Ankole and Kigezi
Region II — Mubende, Mengo and Toro
Region III — Mbale, Bugisu, Bukedi, Busoga, Teso, Lango, Acholi, Bunyoro, West Nile and Karamoja.

All hides and skins sold pass through one of these centres and accurate records are kept and published by the Department of Veterinary Services and Animal Industry (1952–1957). Some hides and skins are used for domestic purposes but no data are available which allow an accurate estimate of the extent to which hides and skins are so used. The authors have estimated an error of 2 per cent for cattle and 1·6 per cent for sheep and goats from the difference between the data as published by the Veterinary Department for livestock slaughtered and hides and skins purchased. This is probably the minimum error and Sanders (1958) has estimated that the overall error may be as high as 10 per cent. However, the error produced by the use of hides and skins for domestic purposes is a small constant proportion and has been excluded from the calculations.

Carcass meat is also imported from Kenya into Uganda and during 1957 this amounted to 769 tons. When, however, this quantity is equated to the total proportion, a value of 0·06g protein per person per day is obtained and this, for the purpose of our calculation, has been ignored.

THE COMPOSITION OF BODIES OF CATTLE AND GOATS

Methods

Ten adult cattle were slaughtered and the various parts of the bodies were separated and weighed. The cattle selected were a mixture of Zebu and Nganda types. Four were large Zebu animals purchased from Karamoja district and three were Nganda from the Animal Health Research Centre. The remaining three were of unknown but local origin. A full analysis of seven animal bodies was carried out; the remaining three were partly analysed. Surface fat was separated, the amount of nitrogen was determined in lean meat and the standard factor 6·25 was used for calculating crude protein. The percentage of protein in meat is an average value obtained from the analysis of seven animal bodies. The fat separated contained a small quantity of connective tissues. As it was not necessary to separate fatty tissues from bones completely for the purpose of this paper, the weight of fat and bones together was considered. The data given for bones are approximate and, therefore, no standard error was calculated.

The percentage of protein in offals was determined from random sampling of offals from three animals and, as the results obtained agreed with the F.A.O. (1953) and PLATT's (1945) tables, they were accepted.

Three goats obtained from the Livestock Experiment Station, Entebbe, were slaughtered and the relation of carcass weight and organs to body weight was determined. The chemical composition of goat meat was determined and used for this calculation, but for the sheep the factor given by PLATT (1945) was used. Average live weights for sheep, goats and cattle are those given in the *Report* of the Agricultural Productivity Committee (1954). The contribution of meat from sheep and goats in Uganda is smaller than that of beef and amounts to some 23 per cent of the total consumption for a six-year period. The possible error produced, therefore, by using standard factors is of little nutritional importance and because of this the work carried out was primarily concerned with cattle.

Indigenous cattle have a considerable proportion of edible offals, all of which are consumed by the population with the exception of blood which is utilized only in some districts. It may be noted that the stomachs and intestines are included as edible offals as they are accepted locally as food.

The average percentage of protein in offals was found to be 18·0 and that of beef 19·6.

The value for protein in offal is higher than that accepted by the F.A.O. but appears to be due to the smaller quantity of fat present in Zebu than in European cattle. The percentage of protein in trimmed meat agrees with data given by the F.A.O. for lean meat.

RESULTS

Table 1 gives the composition of cattle bodies expressed as a percentage of their live weight. Body sections and organs were expressed as percentages of

Table 1. Average composition of slaughter cattle

Live weight	Percentage live weight composition of bovine bodies						
	Carcass*	Head	Hide	Lungs, liver, kidney, heart, brain, tongue	Stomach and intestines	Blood	Gut contents and losses
560 *lb*	46·1	5·9	8·0	2·7	7·6	3·3	26·7
Standard deviation	4·54	0·45	1·33	0·41	0·37	0·50	4·32
Standard error	1·72	0·17	0·50	0·13	0·12	0·19	1·63

Live weight	Percentage live weight composition of carcass		
	Lean meat	Bones and fatty tissues	Bones as trimmed†
560 *lb*	22·0	24·1	16·1
Standard deviation	1·99	4·25	—
Standard error	0·75	1·61	—

* 'Carcass' means flesh and bones (excluding head) only.
† 'Trimmed bones' means bones from which meat and fat were cut off but not scraped.

Table 2. Carcass and bones expressed as per cent of live weight

Description of beef	Live weight	Carcass	Bones
Thin: U.S.A. grade utility	375 *kg* (827 *lb*)	52·00	9·89
Medium: U.S.A. grade commercial	408 *kg* (899 *lb*)	53·92	8·63
Fat: U.S.A. grade good	446 *kg* (983 *lb*)	56·05	8·41
Very fat: U.S.A. grade choice and prime	487 *kg* (1074 *lb*)	59·55	7·15

live weight and, from the variation of these percentages, which include experimental error, standard deviation and standard error were calculated.

Stomach contents and losses were obtained by subtraction of the sum of the other parts of the bodies from the live weight. Direct determination gave very misleading results mainly caused by the escape of gases from the rumen and the loss of body fluids. It can be seen from *Tables 1* and *2* that the percentage of carcass in Uganda cattle is much smaller than in European and American beef cattle, while the percentage of bones in the carcass is greater. It should be noted that in most of Uganda cattle are kept as a social asset and not for profit; consequently the data given in this paper are not intended to apply to cattle in general, which are usually younger and in better condition, than slaughter cattle.

Table 2 gives the percentages for carcass and bones as calculated from F.A.O. (1953) tables.

Availability of meat in Uganda

The aim of the calculations shown below is to give a picture of availability of meat per head of population and an indication of the balance between the increase of population and increase of production. The analysis of cattle bodies shows clearly that there is a considerable difference between local breeds and those from America and Europe. A direct comparison, therefore, of data expressing either live weights or carcass weights of cattle is misleading and incorrect.

A higher proportion of offals is used in Uganda than in Europe and America and this, since they contribute considerably to the nutrition of the local population, must be taken into account.

The accepted way of expressing protein requirements of people is by using the value for grammes of protein per head per day. This method is used by the Applied Nutrition Unit, London (1957) and the National Research Council, Washington (1953). The same system is applied by the F.A.O. in their *Food Balance Sheets* (1953).

To facilitate the expression of meat and offals as grammes of protein, a value for ' lean meat equivalent ' was calculated. This term expresses the weight of lean meat per animal plus that weight of lean meat which would contain the same weight of protein as the edible offals. In calculating the availability of meat for consumption in Uganda in the past, little account has been taken of the edible offals, nor was any correction made for waste such as bones. Expression of meat as lean meat equivalent takes account of these factors. Thus, an animal of average size in Uganda produces:

Average live weight	*Lean meat (19·6% protein)*	*Edible offals*
Cattle 560 lb	123 lb	76 lb (18% protein)
Goats 50 lb	11·16 lb	10·25 lb (16% protein)
Sheep 57·50 lb	6·9 lb	7·6 lb (16% protein)

By adjusting the weight of offals to lean meat equivalent, the average total yield of lean meat is as follows:

Cattle 193 lb; Goats 19·53 lb; Sheep 13·18 lb

By multiplying the lean meat equivalent by the total number of hides and skins sold through trade, the yearly value of animal products in Uganda expressed in terms of lean meat can be calculated and is shown in *Table 3*.

Table 3. Production of tons of lean meat equivalent per year

Description	*1952*	*1953*	*1954*	*1955*	*1956*	*1957*
Beef	26 528	29 395	30 338	27 297	31 654	34 236
Goat	7 393	6 987	8 463	8 852	9 709	8 998
Mutton	389	382	497	551	682	673
Total	34 310	36 764	39 298	36 700	42 045	43 907

Table 4. Average meat consumption of Protectorate in lb per person per year

Description	1952			1953			1954			1955		
	L.M.E.	B.M. excl.	B.M. incl.	L.M.E.	B.M. excl.	B.M. incl.	L.M.E.	B.M. excl.	B.M. incl.	L.M.E.	B.M. excl.	B.M. incl.
Beef	11·40	15·28	19·72	12·45	16·68	21·54	12·66	16·96	21·90	11·22	15·03	19·41
Goat	3·18	3·94	5·31	2·96	3·67	4·94	3·53	4·38	5·90	3·65	4·53	6·10
Mutton	0·17	0·19	0·28	0·16	0·18	0·27	0·21	0·24	0·35	0·23	0·26	0·38
Mixed total	14·75	19·41	25·31	15·57	20·53	26·75	16·40	21·58	28·15	15·10	19·79	25·89

Description	1956			1957			Average of 6 years		
	L.M.E.	B.M. excl.	B.M. incl.	L.M.E.	B.M. excl.	B.M. incl.	L.M.E.	B.M. excl.	B.M. incl.
Beef	12·81	17·17	22·16	13·67	18·32	23·65	12·37	16·58	21·40
Goat	3·93	4·87	6·56	3·59	4·45	5·00	4·47	4·31	5·80
Mutton	0·28	0·32	0·47	0·27	0·31	0·44	0·22	0·25	0·37
Mixed total	17·02	22·36	29·19	17·53	23·08	29·09	16·06	21·14	27·57

NOTE: L.M.E. = Lean meat equivalent.
B.M. excl. = Meat as sold by butchers including bones, excluding edible offals.
B.M. incl. = Meat as sold by butchers including bones, including edible offals.

The *Report* of the Agricultural Productivity Committee (1954) represents pounds of carcasses or, in other words, meat as sold by butchers. To compare this quantity with the value for lean meat equivalent it is necessary to multiply the lean meat equivalent by the following factors:

Beef 1·34: Goats 1·24: Mutton 1·14

When both offals and bones need to be included, a further set of factors to express lean meat equivalent as pounds of meat is necessary, viz.:

Beef 1·73: Goats 1·67: Mutton 1·65

The factors above were used to calculate *Table 4*, which compares the average consumption of lean meat equivalent with meat as sold by butchers,

Table 5. Meat consumption in Uganda expressed as lb of lean meat equivalent (L.M.E.) consumed per person per year

Meat	*Region*	*1952*	*1953*	*1954*	*1955*	*1956*	*1957*
Beef	*I*	5·87	5·92	7·40	6·82	7·99	9·31
Goat		1·25	1·35	2·26	2·79	3·01	3·23
Mutton		0·08	0·12	0·25	0·43	0·55	0·55
Mixed (total)		7·20	7·39	9·91	10·04	11·55	13·09
Beef	*II*	11·89	11·93	12·63	12·05	12·22	12·78
Goat		3·14	2·67	3·10	3·34	3·42	3·34
Mutton		0·13	0·12	0·12	0·13	0·16	0·15
Mixed (total)		15·16	14·72	15·85	15·52	15·80	16·27
Beef	*III*	12·59	15·56	14·98	12·74	15·24	16·01
Goat		4·04	3·80	4·29	4·15	4·60	3·88
Mutton		0·22	0·20	0·23	0·18	0·22	0·21
Mixed (total)		17·85	19·56	19·50	17·07	20·06	20·10

Table 6. Grammes of proteins consumed per person per day in Uganda (Meat and edible offals)

Region	*1952*	*1953*	*1954*	*1955*	*1956*	*1957*	*Average of 6 years*
I	1·75	1·80	2·41	2·45	2·81	3·19	2·40
II	3·69	3·59	3·86	3·78	3·85	3·96	3·79
III	4·35	4·76	4·75	4·16	4·89	4·90	4·64
Whole Protectorate	3·59	3·79	3·99	3·68	4·15	4·27	3·91

excluding offals, over a six-year period. It was not feasible to sub-divide the data of available meat into any smaller areas than those of the three hide-buying centres, as exact numbers of hides originating in each district are not available. However, the numbers of hides which pass through these centres are a fair representation of the number of slaughtered stock and, therefore, of the amount of available meat. The lean meat equivalent available in these regions is tabulated in *Table 5*. To compare the meat availability in Uganda with other parts of the world as published by the F.A.O. (1953) in *Food Balance Sheets*, *Table 6* was calculated. This shows the number of grammes of proteins purchased per day available from beef, mutton and goat meat. Examples of the availability of meat in other countries are given in *Table 7*, compiled from the F.A.O. publication.

Table 7. Total weight of animal protein per head per day from all sources (grammes)

Country	Description	Per year		Grammes of protein per head per day	Total grammes of animal protein per head per day from all sources
		kg	lb		
Argentina 1951	Beef and veal	83·1	183·1	36·0	
	Mutton	4·0	8·8	1·3	
	Total	87·1	191·9	37·3	65·1
U.S.A. 1952	Beef and veal	24·9	54·9	10·7	
	Mutton	1·7	3·7	0·6	
	Total	26·6	58·6	11·3	60·7
Switzerland 1951	Beef and veal	18·8	41·4	7·7	
	Mutton	0·4	0·9	0·1	
	Goat	0·3	0·7	0·1	
	Total	19·5	43·0	7·9	52·0
Ireland 1951	Beef and veal	14·8	32·6	5·9	
	Mutton	4·4	9·7	1·3	
	Total	19·2	42·3	7·2	48·5
France 1951	Beef and veal	23·0	50·7	9·5	
	Mutton	2·5	5·5	0·8	
	Total	25·5	56·2	10·3	43·5
United Kingdom 1951	Beef and veal	15·9	35·1	5·4	
	Mutton	8·1	17·9	2·7	
	Total	24·0	53·0	8·1	43·4
West Germany 1951	Beef and veal	12·4	27·3	5·2	
	Mutton	0·4	0·9	0·1	
	Goat	0·2	0·4	0·1	
	Total	13·0	28·6	5·4	36·9
Austria 1951	Beef and veal	13·8	30·4	5·8	
	Mutton	0·4	0·9	0·1	
	Goat	0·1	0·2	0·1	
	Total	14·3	31·5	6·0	35·7
South Africa 1952	Beef and veal	27·4	60·4	11·5	
	Mutton	7·5	16·5	2·6	
	Total	34·9	76·9	14·1	25·9
Italy 1951	Beef and veal	6·9	15·2	2·9	
	Mutton	1·1	2·4	0·4	
	Total	8·0	17·6	3·3	20·5
Yugoslavia 1951	Beef and veal	4·9	10·8	2·2	
	Mutton, lamb and goat	2·1	4·6	1·0	
	Total	7·0	15·4	3·2	20·0

Table 7 (continued)

Country	*Description*	*Per year*		*Grammes of protein per head per day*	*Total grammes of animal protein per head per day from all sources*
		kg	*lb*		
Honduras 1951	*Beef and veal*	25·4	56·0	10·2	
	Total	25·4	56·0	10·2	18·0
Greece 1951	*Beef and veal*	2·8	6·2	1·2	
	Mutton	4·0	8·8	1·4	
	Goat	1·9	4·2	0·7	
	Total	8·7	19·2	3·3	17·1
Southern Rhodesia 1951	*Beef and veal*	24·9	54·9	10·0	
	Mutton	0·5	1·1	0·1	
	Goat	0·7	1·5	0·3	
	Total	26·1	57·5	10·4	16·0
Turkey	*Beef, veal and buffalo*	6·4	14·1	2·7	
	Mutton	3·7	8·2	1·2	
	Goat	3·1	6·8	1·2	
	Total	13·2	29·1	5·1	13·1
Japan 1951	*Beef and buffalo*	0·6	1·3	0·3	
	Total	0·6	1·3	0·3	11·8
Egypt 1951	*Buffalo, beef and veal*	7·8	17·2	3·0	
	Mutton	1·2	2·6	0·4	
	Goat	0·6	1·3	0·2	
	Total	9·6	21·1	3·6	11·4
Ceylon	*Beef, veal and buffalo*	2·0	4·4	0·9	
	Mutton and goat	0·2	0·4	0·1	
	Total	2·2	4·8	1·0	10·0
Philippines 1952	*Beef and buffalo*	4·0	8·8	1·4	
	Total	4·0	8·8	1·4	9·6
India	*Beef and buffalo*	0·5	1·1	0·2	
	Mutton	0·3	6·6	0·1	
	Goat	0·4	0·9	0·2	
	Total	1·2	8·6	0·5	5·6

DISCUSSION AND CONCLUSION

The results given show that the body proportions of Uganda cattle are much inferior to European or American breeds for beef production. The much higher proportion of inedible products such as bones and rumen contents indicate that production could be increased by at least fifteen per cent without increasing the cattle population if cattle were improved to reach the same standard as European beef breeds. Any widespread improvement of carcass quality, however small, could make a significant increase in the amount of protein available from beef.

At the same time, the total availability of proteins from beef, mutton and goat meat in Uganda during 1952 can be favourably compared with the more developed countries such as Italy, Turkey, Greece and Yugoslavia and is much higher than in India, the Philippines, Ceylon and Japan (F.A.O., 1953). Comparison with these countries after 1952 is not possible as no later data are available for the consumption of these meats. *Table 7* shows clearly that beef, mutton and goat meat are not the only sources of animal protein in any country. Indeed products such as eggs, poultry, fish, pork, milk, cheese, etc., contribute considerably to the total protein available.

Unfortunately, data for the availability of these products and others peculiar to Africa such as termites, grasshoppers and blood drawn from living cattle for food purposes are not available or are based on more or less inaccurate estimates.

Newton (1958) estimates that at least 3 900 tons of dressed meat is available from game in Uganda each year and Rhodes (1958) has estimated that an average of 25 000 tons of fish was available per year during the period 1952 to 1957. The quantity for 1957 was approximately 35 000 tons of wet fish and the total has shown a steady increase during the last six months. During the last ten years some 300 dams have been stocked with fish and 2 500 fish ponds have been established. A large proportion of these were established in the last few years and have not yet reached full production. These data suggest that an annual average of 10·3 lb of fish per head is available. When the data for the composition of local fish as determined by Bredon and Marshall (1954) are used, it can be calculated that 1·82 g of protein per head per day is obtained from these sources. The average of 1·6 lb of butchers' meat from game per head per year may be calculated as 0·4 g of protein per head per day by using the data given by the F.A.O. for game (1953).

Although poultry husbandry is very primitive, considerable numbers of chickens and eggs are consumed yearly. Some districts already export poultry and eggs and, according to the *Annual Report* of the Department of Veterinary Services and Animal Industry (1956) one district exported 40 000 fowls and 350 000 eggs. The poultry industry is rapidly developing and the standard of husbandry is steadily improving. Considerable quantities of milk are consumed in urban and pastoral areas. Randall (1957) has estimated this at approximately 52 pints per head per year from local milk, and data for imports published by the Department of Veterinary Services and Animal Industry (1957) can be calculated as 2·65 pints per head per year from Kenya milk. The total amount of milk represents 2·97 g of protein per head per day. The pig industry is still in an embryonic

stage but, with the appointment of a pig and poultry extension officer, it is hoped that both industries will develop considerably.

Although this review has no direct bearing on this paper, it is necessary to enable a comparison to be made with other countries as beef, mutton and goat are not the only sources of animal protein.

It can be noted from the *Tables 3*, *4* and *6* that there is a constant increase of meat production and a steady increase in the number of grammes of meat protein available per head per day.

These tables show that the meat industry is not only keeping pace with the growth of population but is ahead of it. It should be noted that the production of meat is increasing despite the large increase of cultivated land.

It must be emphasized that this type of calculation can by no means be regarded as final. These data take no account of the distribution of meat between urban and rural areas and between and within families. It is well known that more meat per head is consumed in urban than in rural areas while, in Uganda, the best part of the food is consumed by the adult males, and children under one year of age consume very little meat.

The problem of availability of commodities must, of course, be handled simultaneously with that of distribution and, in many instances, the availability of food is the limiting factor.

SUMMARY

An analysis of the body proportions of Zebu cattle intended for slaughter was carried out and the weights of various parts were expressed as percentages of live weight.

This analysis indicates that Zebu cattle in Uganda yield a lower percentage of ' edible portion ' than is normally used when calculating the animal protein intake of a population but the eating habits of the local population are such that a much larger proportion of offals is consumed than by European-type populations and data given in various nutritional tables of ' edible portion ' of animals are not directly applicable.

A simple factor called ' lean meat equivalent ' is proposed, which expresses all the edible portions of cattle bodies as lean meat containing 19·6 per cent protein. This value was obtained from local slaughter cattle which are much less fat than European-type cattle.

Other factors were calculated, to enable a comparison to be made between ' lean meat equivalent ' and meat as sold by butchers, both with and without edible offals. Factors were also calculated for sheep and goats.

An attempt is made to calculate the availability of meat from domestic livestock and to compare it with other countries. To facilitate this comparison, meat available is also expressed as grammes of protein per person per day.

A short review of the availability of animal proteins in Uganda from other sources is given.

ACKNOWLEDGEMENTS

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Book Reviews

FERTILISER USE: NUTRITION AND MANURING OF TROPICAL CROPS

A. Jacob and H. von Uexküll. Translated by C. L. Whittles. Verlagsgesellschaft für Ackerbau m.b.H.: Hannover, 1958. $x + 491$ *pp.* (illus.)

Those who acquire enjoyment by browsing through library shelves usually possess special enthusiasm for particular types of books. The reviewer has always enthused over those little technical gems dealing with tropical plantation crops. Full of wise practical advice and eminently readable, they have, however, until now lacked a modernized version necessarily laced in the precision of scientific facts. *Fertiliser Use* by Doctors Jacob and Uexküll unquestionably fills this need. Comprehensively referenced, very informative and pleasingly bound, the book is highly recommended as a volume for general reference to those actively engaged in tropical crop husbandry.—T.A.J.

THE STAPLE FOOD ECONOMIES OF WESTERN TROPICAL AFRICA

Bruce F. Johnston. Stanford University Press: California, 1958. $xi + 305$ *pp.* $6.00 (U.S.A.)

This work worthily maintains the standard we have become accustomed to expect in the publications of the Food Research Institute of Stanford University. Following the traditions of that Institute, the approach is primarily economic but with much more than a side-glance at climatic, biological and farming considerations.

The merit of the book is twofold. First, it collects statistics and includes maps which make clearer than has been done before the actual distribution of food crops in West Africa. The contrast between the ' yam civilization ' of the eastern part of the Guinea coast and the rice zone further west emerges strongly. Secondly, it introduces us to new problems. There is a very close analysis of the value of different food crops in terms of calories produced per acre, per man-day, and per unit of time; though even this is possibly not quite close enough, for it is not clear that the inedible portions of different products as harvested have been sufficiently taken into account. This is a type of approach which is only just beginning to be made in detail for tropical crops, and is obviously going to assume increasing importance. Another striking fact is the rate of increase of imports of wheat flour, and of bread consumption, throughout West Africa. Nutritional problems are referred to intermittently but in some detail.

The whole work impresses by its care and scholarship, and it cannot be ignored by serious students of the area. Tropical agriculturists owe a debt to Mr Johnston for the laborious research that must have gone into compiling this information for our benefit.—G.B.M.

AN ECONOMIC SURVEY OF THE SISAL INDUSTRY OF TANGANYIKA

C. W. GUILLEBAUD. Tanganyika Sisal Growers' Association and James Nisbet & Co. Ltd: Welwyn, 1958. *xiii* + 119 *pp.* 15*s*

It is not often that such a distinguished economist is persuaded to turn his attention to a tropical crop; the result of Mr GUILLEBAUD's labours is a lucid and informative account of the Tanganyika sisal industry. The treatment is mainly historical and factual; controversy is eschewed, though the author does allow the idea to be inferred that the Tanganyika Government's taxation policy has been less than kind to the sisal industry.

Amongst the main subjects dealt with are sisal prices in relation to production and consumption, the cost of production, labour relations and marketing. There are many useful references to the other hard fibres competitive with sisal, especially manila and henequen, and the importance of the rapidly increasing Brazilian production of sisal is suitably stressed, though it is a pity that more information about production conditions in countries other than Tanganyika could not have been included.

For the agriculturist the author's most interesting deduction is perhaps that continuous expansion in sisal output, especially in Africa, seems likely to be at an end. As to the economic prospects of the industry, he is careful to avoid forecasts. But this is a book which all who are directly concerned with sisal production in Tanganyika will want to read for themselves.—G.B.M.

FODDER FARMING IN KENYA

G. R. HENDERSON and P. T. PRESTON. Egerton Agricultural College Technical Publication; East African Literature Bureau: Nairobi, 1959. *x* + 149 *pp.* (illus.) *Sh* 10.50

Dry season feeding of cattle has always been the Achilles' heel of Kenya farming. Those who take the advice given in this sensible little book will go far to solve the problem; its primary usefulness is for European farmers, but increasingly the African who undertakes intensive stock-keeping must follow similar practices. Heavy emphasis is laid on silage-making, which is explained simply and fully to assist those who have not attempted it under local conditions. Useful chapters on feeding standards and feeding programmes are included.

This is an admirable example of the type of local publication on different aspects of farming which should be beginning to supersede generalized textbooks on agriculture in the tropics.—G.B.M.

THE SOUTH AFRICAN SUGAR YEARBOOK 1957–58

Compiled and issued by the staff of the *South African Sugar Journal*: Durban, 1958. 275 *pp.* (illus.) 10*s*

This 28th number of the *Year Book* is a valuable reference book and guide principally for the sugar industry of South Africa, but information is also given on sugar production in other African territories. Detailed data and

addresses are available for chemists, technologists, engineers, cane growers, research workers and manufacturers.

A most popular and informative addition to this current issue is the increased number of photographs, both in colour and in black and white, illustrating various aspects of the industry, but more particularly that of machinery for field and factory.—J.S.C.

HORTICULTURAL ADVANCE

Vol. 1, December 1957

Horticultural Research Institute: Saharanpur. Annual subscription: *Rs* 12*s* inland, *Rs* 15*s* abroad

This new journal published by the Horticultural Research Institute, Saharanpur, India, is most welcome. There are very few publications dealing with horticultural research work in the tropics. Well produced and illustrated, this first volume contains a number of articles dealing with mangoes, control of certain diseases in persimmon and plums, studies in the preparation of papain and a number of other problems.

It is hoped that in future issues its scope may be widened to include articles on vegetables and flowers and its initial high standard maintained. This is a useful publication for those interested in tropical horticulture.—J.S.C.

ECONOMICS AND AGRICULTURE

A. Martin. Routledge and Kegan Paul: London, 1958. *viii* + 169 *pp.* (illus.) 21*s*

It is probably true to say that the majority of agricultural economists are trained first as agriculturists and subsequently as economists. Certainly in the past and in some countries there has been a weakness in the profession of agricultural economics in that the practitioners have not always displayed a dedicated evangelism for the economic discipline.

It is welcome therefore to see the appearance of books on the basic principles of economics written for agricultural students. Such publications should greatly strengthen the teaching of agriculturists and probably some agricultural economists of the future.

Miss Martin's book provides a compact, yet readable and sound introduction to the principles of economics for the agricultural reader. Her first six chapters on price, demand, supply, competition, etc. admirably state the fundamentals that form the very *raison d'être* of the book. Her two chapters on 'Agriculture and Public Policy' are also most welcome. All agriculturists, and perhaps for that matter politicians, should be capable of thinking more clearly on this subject than they often appear to do at present. Only too often today the economist, agricultural or otherwise, is stigmatized as being against agriculture if he raises any question as to the desirability of introducing a specific measure of assistance to that industry. Unfortunately it is becoming only too common in developing countries for assistance to agriculture to be regarded as the hallmark of a progressive government partly because the richer countries of the world for one reason or another lavish such assistance.

This reviewer would not quite agree with the author's choice of a chapter on 'Land Tenure' to the exclusion of one on Money and General Price Levels. Although land tenure is of particular importance to agriculture and the forms differ because of economic as well as social and political causes, land tenure is not the only or even perhaps the most important peculiar problem of agriculture; an equally important chapter could, for instance, be written on Agricultural Capital. Such subjects indeed seem more purely in the field of agricultural economics. On the other hand changes in the general price level have quite as devastating, though often not so obvious, an effect on agriculture as on industry, and lie in the reviewer's opinion strictly in the field of economics.

However, it is obvious that everything cannot and should not be included in a book of this kind and it is largely a matter of choice where to draw the line. The author is to be congratulated on succeeding so well in the most important main object of her book.—A.L.J.

THE BULK HARVESTING OF ORCHARD FRUIT

G. E. Tidbury. Commonwealth Bureau of Horticulture and Plantation Crops: Commonwealth Agricultural Bureaux, Farnham Royal, Bucks. *Digest No. 1*, 1958. *v* + 38 *pp.* (illus.) 5*s*

This concise, well illustrated, booklet reviews the most recent methods of bulk harvesting of apples, cherries, citrus, olives, grapes, other orchard fruit and walnuts. These have been developed in temperate and sub-tropical countries, principally on fairly flat lands with good communications and roads. The main advantage of bulk harvesting has been shown to be the elimination of the field crate or box, hence less labour requirement, and finally, a cheaper cost. At the same time, by the use of such methods, the fruit apparently suffers less damage. In these days of highly competitive markets, these factors are extremely important.

It is difficult to see, however, the direct application of some of the methods described to the tropics, where a great deal of fruit is grown on very undulating country and in the case of citrus, under high rainfall conditions, necessitating the provision of deep drains. Nevertheless the problem of improving and cheapening harvesting standards is as great, if not greater, in these areas.

This first digest, which it is hoped will be the forerunner of many such useful publications, provides advisory officers and practical horticulturists alike with an excellent summary of methods, which they may wish to try out or modify, according to circumstances.—J.S.C.

MACHINES ON THE FARM

H. J. Hine. Odhams Press Ltd: London, 1959. 224 *pp.* (illus.) 25*s*

Mr Hine already enjoys a reputation as the author of authoritative and useful books on farm machinery, which the present volume will sustain. It does not deal with tractors, and is therefore complementary to his earlier book *Tractors on the Farm* which has already run through several editions.

All kinds of machines generally used in the United Kingdom for the cultivation, harvesting, and farm processing of crops and grass are dealt with; the book opens with ploughs and closes with explosives. It does appear, however, to belie its title by omitting all reference to machines used in animal husbandry, e.g. for milking, dairy work and shearing; while machinery used on special crops such as hops or flax is also omitted.

The sub-title of the book is 'Time and Labour-saving Methods of Operation'. The machines are not described; the text deals with their maintenance and adjustment and with what may be called the technical strategy of deploying them to the best advantage. For United Kingdom conditions, this is extremely well done. There are as yet few operators in the tropics with the skill to profit from the finer points made in this book; but it may at least show them how far they have to go, and how much has already been learned in countries where mechanization is older.—G.B.M.

OBITUARY

C. Y. Shephard, C.B.E., PH.D.

Dr C. Y. Shephard, who died in Trinidad on 16 June, was Carnegie Professor of Economics in the Imperial College of Tropical Agriculture from 1925 to 1953, and Vice-Principal during the last six years of that period. A long succession of students thus came under his guidance, including many now senior members of the Overseas Agricultural Service. They remember him gratefully as an inspiring teacher. He will be remembered also for a variety of outstanding services to the West Indies and to tropical agriculture generally. Amongst other things, he was Editor of *Tropical Agriculture* in its earliest years (1924–28).

Cecil Yaxley Shephard was born in 1900 and educated at Bridport Grammar School. Graduating with first class honours from the London School of Economics in 1923, he was appointed Reader in Economics at the I.C.T.A. in 1924 and selected in the following year to fill the newly created Carnegie Chair. He began at once to study the leading agricultural industries of the West Indies, and quickly established a reputation for clear analysis and a sound grasp of essentials. This was enhanced by his facility in exposition, whether by the pen or by the spoken word.

One of Shephard's earliest major publications was an account of the cacao industry of Trinidad, a subject in which he remained interested to the end of his life. The industry was, at the time, in a state of decline and regarded by many as beyond recovery. From painstaking surveys, incorporating a system of recording the performance of individual trees, Shephard was able to formulate plans for its rehabilitation and provide it with new hope. He was one of the first to appreciate how the researches of his colleagues in other departments could be applied practically to the problem of rehabilitation, and his cooperation and advocacy were a great encouragement to them.

Another of his main contributions was to peasant agriculture, in which his interest was stimulated by a tour in West Africa in 1934. In a later survey of peasant agriculture in the Leeward and Windward Islands he produced a model for similar surveys elsewhere, leading to an important refinement in the methods of investigating the economics of peasant farming. In 1951 he was able to make another and more extensive tour of African territories to study developments in this subject.

Shephard's public services in Trinidad included, at one time or another, membership of the Board of Education, the Joint Sugar Board, the Cocoa Board and the Copra Committee, and the presidency of the Cocoa Planters' Association and the West Indian Limes Association. A public activity of a rather different kind was his founding in 1932 of the Trinidad and Tobago Historical Society. As secretary for four years and subsequently president for another thirteen he stimulated and collated some most interesting researches into the history of the islands as far back as records go. His own *British West Indian Economic History* was published in 1939. During the war he threw himself with characteristic vigour into organizing ground training for the Trinidad Air Training Scheme; and when that scheme had done its work he served as District Warden for Civil Defence for the rest of the emergency.

He was frequently in demand to investigate and report upon economic questions in the various West Indian islands, and in 1944 was invited to visit Fiji and the Western Pacific High Commission Territories and study the agriculture of that region, on which he duly reported. In 1946 he investigated the sugar industry of Barbados on behalf of the Government. His many public services were recognized by his appointment as C.B.E. in 1948. Since leaving the I.C.T.A. in 1953 he had been executive secretary (agricultural economics) with the Caribbean Commission.

Cecil Shephard's public achievements had the background of a happy home, in which students and colleagues found always a friendly welcome and generous hospitality. Our deep and respectful sympathy goes to Phyllis Shephard and her son and daughter in their loss.

Recent Publications

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OTHER PUBLICATIONS

Flora of Trinidad and Tobago. (The early parts were edited by the Department of Agriculture of Trinidad and Tobago but editing has now been taken over by the Botany Department of the Imperial College. The Flora may be obtained from either address.)

Volume I—Ranunculaceae to Araliaceae (8 parts and index), 26*s* 6*d*

Volume II—Rubiaceae to Labiatae (6 parts to date), 23*s* 7½*d*
Further parts are in preparation

These and earlier publications can be obtained from the Library and Publications Department, Imperial College of Tropical Agriculture, Trinidad

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The following book written by a member of the staff has recently been published:

Insect Life in the Tropics, by T. W. Kirkpatrick. Longmans, Green: London. 35*s*

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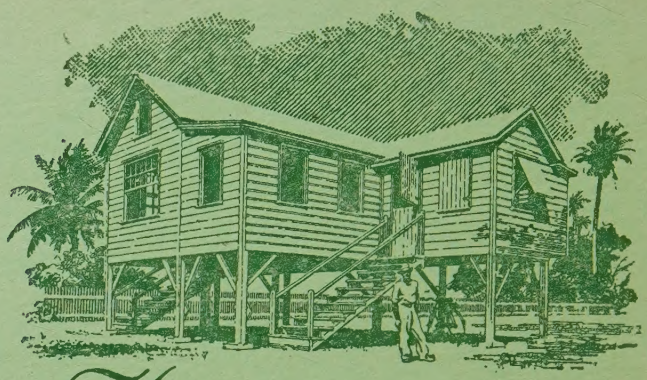

This is a House—

an important house, because it is the home of Bridgelall, his wife Rhonie and their six children—Ramkissoon, Rookmin, Sancherry, Harold Kissoon, Bairan, and Saladeo the baby. It stands on Lot 223 in the Success Housing Scheme, Demerara.

Bridgelall is a cane cutter at La Bonne Intention—one of the Booker group of sugar estates in British Guiana. He is an important person, both to British Guiana and to Bookers; for without Bridgelall and his fellow workers Bookers could not have made 200,000 tons of cane sugar for the Commonwealth last year.

Bridgelall owns this house. It cost him £300, of which £200 was provided by the Sugar Industry Labour Welfare Fund as an interest-free loan which he pays back at the rate of 8/4d. a week.

Bridgelall is one in 30,000—the 30,000 men and women in the Booker Group of Companies in British Guiana, Trinidad, Africa, Canada and England; the people who, much more than ships and shops and sugar estates, make the Booker Group what it is today.

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